CONTROL

A TECHNICAL JOURNAL FOR DESIGNERS AND USERS OF ELECTRICAL, ELECTRONIC, HYDRAULIC, MECHANICAL AND PNEUMATIC CONTROL SYSTEMS AND INSTRUMENTATION

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VOL 2 NO 18 DECEMBER 1959

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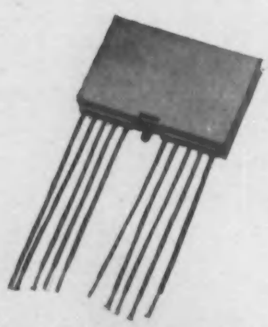

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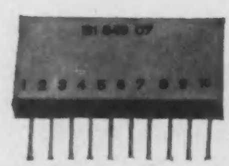

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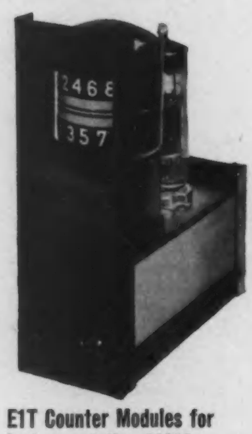

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CONTROL

PUBLISHERS COLUMN

A GUIDE TO CONTROL

The buyer's guide in this issue is the result of many months' hard work. We sent out a large number of forms asking firms to tick off their products. The listing of the firms was done automatically by I.C.T., and the work involved after we had received the questionnaires back from the firms was quite small. The hardest jobs were the compilation of the master product list and persuading firms to send the forms back to us.

Apart from those who failed to return brochures because of lack of interest, we had about fifty completed forms returned neatly ticked, but with no identification.

The guide covers eight hundred firms, classified into six hundred and forty headings of control equipment. Apart from this supplement we run a reader enquiries service for more detailed information on any of the products.

A thing that caused us some delay was the time required for the large firms to fill in a form. Eight extensive organizations were six weeks late with their entries; their explanation was that they had to send the form to all their subsidiaries. It almost seems that some of the parent companies do not know what their offspring are making! And one further example came to hand recently when we received a form from a *very* large manufacturer of electrical equipment; it had only ten entries and had taken two months to complete. Was their Head Office so completely in the dark?

We had many other worries but we think that it has been worth while. There may still be few headings that need improvement and if you have any comments —complimentary or otherwise—do please write in and tell us.


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Contributions to polarography

SIR: I have read with interest the letter from W. E. Lamb of Cambridge in the latest issue of CONTROL. In preparing my article on Polarography* I admit I was somewhat handicapped by the need to condense such a wide subject into 3500 words. As I stated in the text, the article was 'only intended as a brief introduction' to the subject. In the interests of brevity, therefore, I have undoubtedly missed out a number of important facts and I would agree with Mr. Lamb that one of these is the development of the Univector attachment for use in A.C. Polarography. It is quite true that the Cambridge Instrument Co. have made important contributions to the science and technology of polarography from the very early days and I would ask them to accept my apologies for omitting to mention this in my recent article on the subject.

B.S.I.R.A., Chislehurst D. G. ANDERSON

* CONTROL, *August, page 80*

Should we count civil engineers?

SIR: I hestitate to re-enter the pages of CONTROL so soon after handing over the editorial reins. But since I was originally responsible for the article* which dismayed Mr. Whitehouse, I should like to comment briefly on his letter†. Certainly some professional civil engineers are interested in automatic control, particularly those concerned with public utilities such as water, sewage and gas works. Yet true civil engineering, unlike control engineering, looks more towards the statics than the dynamics of a system.

Indeed, civil engineers engaged on control system work are probably better thought of as 'engineers' or 'professional engineers' than either 'civil engineers' or 'control engineers'. I suspect that the number of corporate members of the Civils, not also corporate members of the Mechanicals or Electricals, who consider themselves 'control engineers', could be counted on the fingers of one hand, if not on the thumb alone.

Blackie & Son Ltd. CHRISTOPHER T. RIVINGTON

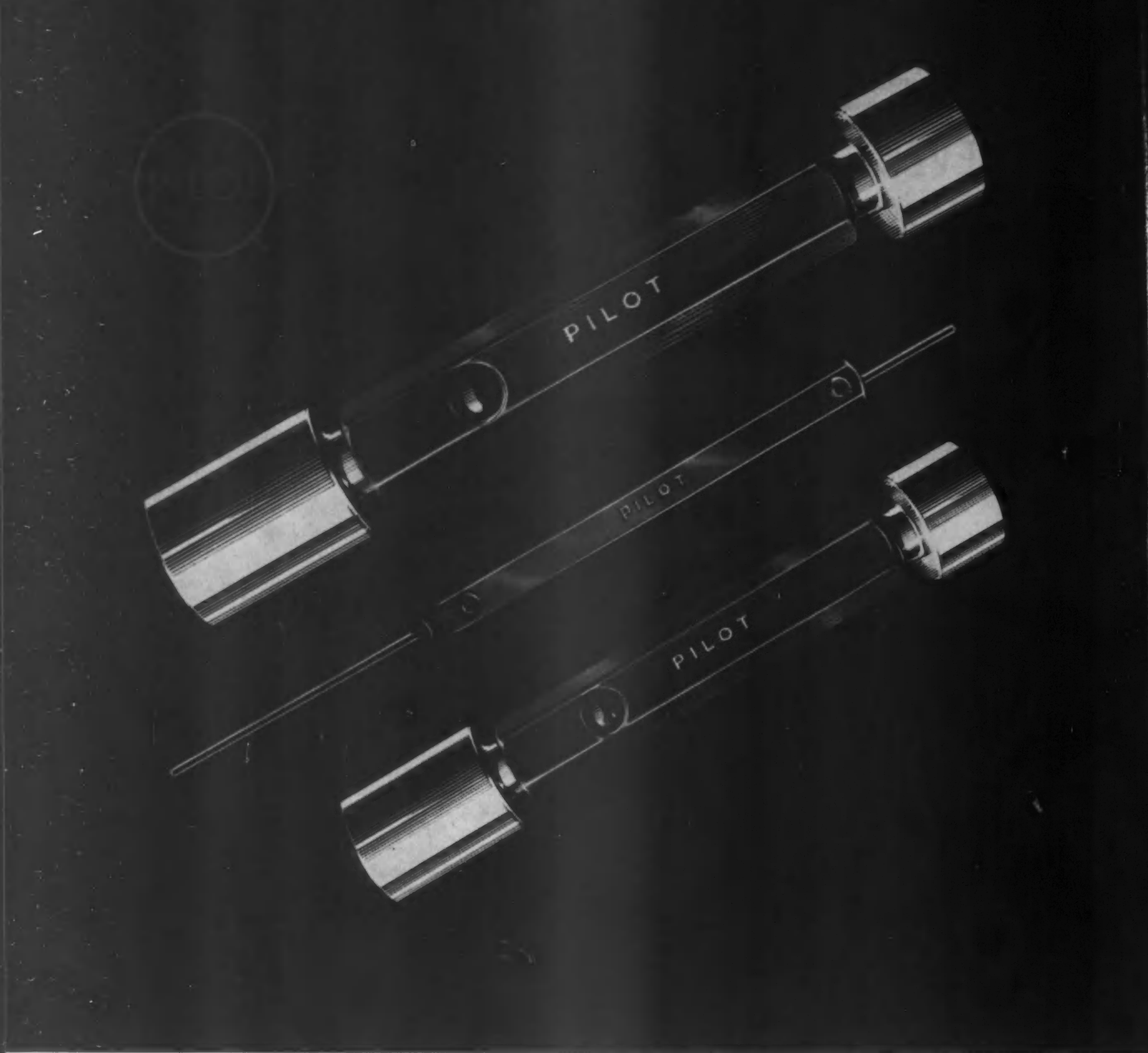
* CONTROL, *September, page 79*
† CONTROL, *October, page 79*

Cry from the heart

SIR: In your editorial of the October edition (of CONTROL), you blithely advocate yet another subject to be included in the student engineer's academic syllabus, as if there aren't enough already! I suppose technological education is the popular sort of thing for engineering journalists to write about these days, but will articles such as your editorial be of much effect? As a recent graduate in electrical engineering, it seems to me that the Universities' and Technological Colleges' Authorities are not lacking in knowledge of which subjects are desirable to include in engineering courses (my own college included 'Economics for Engineers' as an optional subject in a number of courses), but their frightful problem is, which subjects to exclude!

What needs far more critical examination these days, by such journals as CONTROL—if it purports to be interested in the real problems, present and future, of control engineers and not just to ride on the wave of popularity—is the type of education received, before and after the usual college course, especially the latter. Unless we are going to tie our University engin-

Continued on page 97



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Sir!

Contined from page 95

eering departments firmly to industry, i.e. turn them completely into factory technical colleges, it is inevitable that engineering graduates and many post Dip. Tech. students will want further training in industry. There are special technical subjects e.g. logic circuits which some engineers must learn about and it is arguable that there are many subjects e.g. management studies, which to be of any real value are best learnt about in industry, because the problems can there be far better appreciated by the students. The extent of this further training depends on the answer to the yet unsolved problem, are we going to have extended traditional college course with short post graduate training, or keep the present length of college courses and extend post graduate training. Since the government finances most students to a greater or lesser degree these days, its apparent lack of funds is causing the latter course to be increasingly adopted. There is a lot to be said for this, for other than financial reasons, viz.: more than three or four years is a long time in the life of a young student; a student will probably not need to recall much of the wide knowledge gained in an extended course in later life, but will want certain specialised knowledge, the requirements of which he will only know after leaving college. If the other course is to be adopted there is a lot to be said for industry financing far more engineering undergraduates.

In concluding, I admit that the basic education required by the student engineer is very wide, but it isn't much use cramming it all down his throat and giving him intellectual indigestion before he starts work. Better surely, to provide a situation in which he can obtain further training and information when he realises he needs it.

Hayes, Middlesex J. A. WATSON

Come, come Mr. 'Scryer'

SIR: 'Scryer', whose article 'Quo Vadis?' appears in your November issue, seems to feel that our present political masters do not appreciate the importance of the scientist in modern life. He feels that we 'vitally need leaders trained in science, people in high places who can etc., etc., . . . '. My own admittedly somewhat limited dealings with men of science have not given me such a high opinion of the breed that I would be prepared to see them dispose of much more power than they have at present. In my experience the scientist is too often a somewhat narrow-minded person with a liking for ivory towers, and little administrative ability—that is if he is any good as a scientist.

Come, come Mr. 'Scryer', the new Minister for Science may not be an Einstein, but his lack of a Ph.D. need not necessarily mean a lack of sympathy with scientific aims.

Oxford LAURENCE GRIFFITHS

At one with Nature

SIR: I have just seen the November issue of your magazine and I thought that I would write to you on one small mistake which appears to have been overlooked.

In the table appearing in Mr. J. C. Wells' article 'Hydraulic Oils for Power Transmission' our name is given as 'Vacuum Oil Co. Ltd.'—we are, of course, now known as 'Mobil Oil Company Ltd.', our name having been changed in January 1956.

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CONTROL

DECEMBER 1959 VOL 2 NO 18

Worlds to Conquer

THE editor of a technical paper is prone to open the more highly-flown and philosophical of his leading articles with some kind of modest disclaimer. 'Although this is a strictly technical journal' he may begin, or, 'Unpolitical as we are, it will not come entirely amiss if. . . .' Then, his conscience salved, off he can trot on his hobby horse.

We shall not here try to disarm our readers in this way. It is true indeed that, 'strictly', we are a technical journal, and we are glad of it. But the technique that we deal with is one of far-reaching and fundamental importance. The logic which the control engineer has learned to apply so skilfully to his systems is universally valid. The mathematical studies that he pursues are relevant not only to mechanical and electrical but also to economic and (dare we breathe the word?) political systems. Wherever the stability and optimum performance of a dynamic assembly is sought, there the analytical methods of the control engineer can most fruitfully be brought to bear. A paper like CONTROL would therefore be untrue to its title if it confined itself bigotedly to inanimate matter.

On every hand we see that technologists are recognizing the folly of rigid separation between the study of machines and the study of people. Look, for example, at the humanistic titles of some recent lectures to the engineering institutions. Each of these addresses was delivered before an audience of hard-headed professional engineers, every one of them presumably knowing the right name for a spade. So we feel that we are keeping good company when we venture occasionally along a by-path, riding one hobby horse or another (like our brother editors), and doing so to good purpose. Besides, December is a fine month for horses and philosophy, both of them quaint and traditional as the Christmas season demands. A fortnight away from the Christmas holiday as we are, our thoughts cannot but be touched by it, and three weeks away from the year's end, we cannot but think of a year nearly gone and the annual stock-taking that will follow.

Now annual stock-takings may assume many different forms. One of these is a review of the year as a member of an evolutionary progression, and another is a review of the year simply as humanity's latest attempt in the unchanging task of living the good life. To us it seems that, at Christmastime, the latter is the most appropriate kind of assessment. Looked at in this light, has 1959 been very special? Some astounding things have happened in it, things that a few of us have incautiously predicted were not for our own lifetimes at all. We refer of course to the feats of spatial exploration, more notably by the Russians. Spectacular and magnificent achievements they have been; but, it may be said, strictly material in their significance. Indeed, the most dramatic of them have been the accomplishments of a harshly materialistic state, disavowing all spiritual values. Are they therefore irrelevant at Christmas? We would argue that they are not.

In past ages, in the whole of recorded human history before the industrial revolution, lust for power has vented itself in the dominion of one man over another, or over many others. Notoriously, a highly developed moral sense is given to only a few, and by no means always as an accompaniment to intelligence or strength of mind. Able and hard-willed men, clever in the manipulation of their fellows, have thus become greater or lesser tyrants, more or less vicious in their exercise of power according to their lesser or greater endowment of conscience.

To-day it is possible for ability and strength, however unallied with moral sense, to find greater satisfaction in the acquisition and exertion of power over the material world than over humanity. Our electrical slaves are better than whipped Africans, our servomechanisms more potent than beaten serfs. Here, we suggest, may be the greatest gift conferred by technologists upon mankind, and the greater part of this gift may well be the contribution of the systems and control engineer.

Men are both communal and competitive, so naturally their communities compete. How much better it is that they should compete in the technological conquest of the universe, and not of each other. So may come at least peace, if not goodwill. And if the richest and mightiest spend themselves in colonizing the heavens, then perhaps the meek will more quickly inherit the earth.

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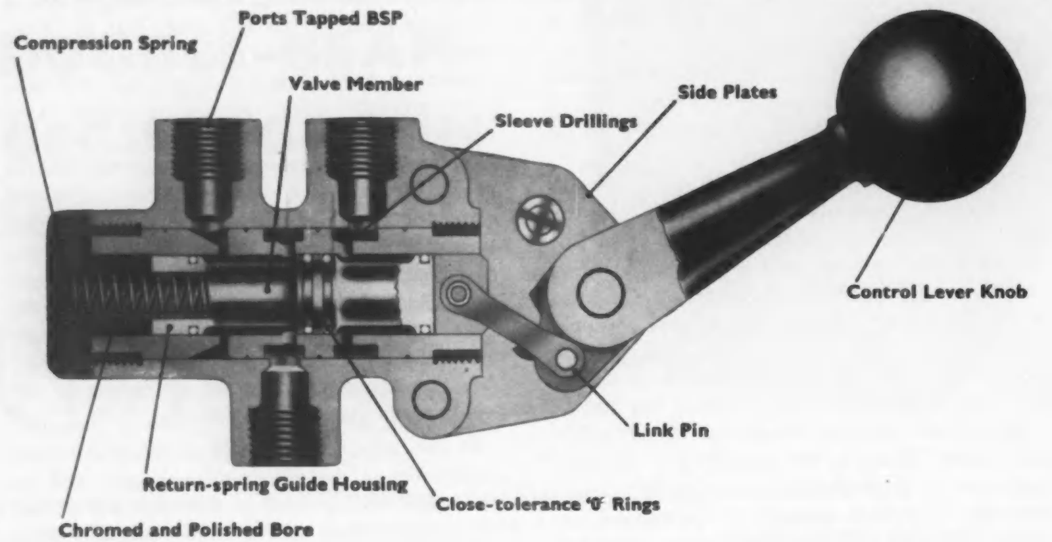

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INDUSTRY'S VIEWPOINT

A monthly article by a prominent man in the control industry on a subject chosen by himself

Sima's President, L. A. Woodhead, Director and General Manager of Cossor Instruments, speculates on the form of . . .

A HIGHLY INSTRUMENTED FUTURE

During the past fifty years or so, more scientific equipment has been developed than in the whole of history, and none of it could have come to fruition without instrumentation—instruments for research, for production test purposes, and the location of faults. Many ideas are now so advanced that suitable instruments must be made *before* work can proceed. This is particularly true of the electronic developments which are essentially and solely of this century, although new ideas are still pouring out from the older chemical and optical industries.

More and more, we reap the benefits of scientific discoveries in our everyday lives. Man-made fibres, plastics, rapid transport, broadcasting—both aural and visual, all are now so much a part of man's existence, that a return to the conditions current at the turn of the century is quite inconceivable. In all these ventures instruments have played a vital part, for they provide the methods of sensing, measuring, indicating and controlling, without which no progress can be made.

In recent years the pace has been quickened by the excursions of earth-made bodies into outer space. The evidence that is being sent back by artificial satellites and other vehicles is already producing a vast bibliography more reminiscent of the works of Jules Verne than of prosaic twentieth-century fact. What next?

Will a living person be landed on the moon and exist there? If the moon can be conquered, are the planets also to be explored? The mind is both overwhelmed by these possibilities and humbled by the vast extent of outer space. Already signals have been received by the radio telescope at Jodrell Bank—which Professor Lovell himself describes as a gigantic scientific instrument—from a galaxy which is 2000 million light years distant.

Coming back to earth, the tendency is to measure smaller and smaller things, moving faster and faster. Measurements in milli-microseconds are becoming commonplace and no doubt we shall soon use micro-microseconds. Some chemical analyses indicate the presence of one part of impurity in ten million parts. Electric current may now be measured in micro-micro-microamperes. And so the story goes on, with instruments achieving an increasing importance in their own right.

In more everyday matters there will be new man-made fibres, the range of applications for metals and plastics will be increased, especially in the regions of high temperatures, newer forms of luminescent lighting will be developed and higher frequencies will be used for broadcasting—all will require new instruments!

Might it not be possible to control, with the aid of punched tape say, trains, ships, aircraft or even motor cars, so that a crew is not necessary, and sensing devices eliminate the possibility of collision? Might it be possible to feed the human mind forcibly with the accumulated knowledge of centuries without the effort of studying? Whether or not such ideas are feasible, they can only come to pass if instruments assist in their design and operation.

L. A. Woodhead

The Russians will overtake us, say a team of six British engineers who visited the U.S.S.R. last May. Here one of the members of the team reviews the report that has just been published by the D.S.I.R., and adds some of his personal impressions

Moscow University

Automatic control in Russia

by **A. ASBURY**, B.SC., M.I.E.E.
Chief Engineer, Kidsgrove Works, English Electric Co.

A REPORT ON THIS SUBJECT HAS JUST BEEN ISSUED* BY the D.S.I.R. It deals with the information obtained by a team of six engineers, led by Professor Tustin, who, in May of this year, visited the U.S.S.R. to discuss automatic control in industry. The visit was arranged by the British Council with the help of the Institution of Electrical Engineers, and was a return visit for one of six Soviet engineers who came to this country in December 1958. This Russian team was drawn largely from the Institute of Automatics and Telemechanics, and was led by Professor B. S. Sotskov.

These were the members of the team that visited Russia in the two weeks between 17th and 31st May, 1959:

Professor A. Tustin	*Department of Electrical Engineering, Imperial College*
A. J. Young	*Head of Central Instrument Laboratory, I.C.I.*
A. Asbury	*Chief Engineer, Kidsgrove Works, English Electric Co.*
R. H. Tizard	*Consultant*
S. S Carlisle	*Head of Physics Department and Deputy Head of Mechanical Working Division, B.I.S.R.A.*
P. H. Hammond	*National Physical Laboratory*

The D.S.I.R. report gives a directory of institutions visited and persons met, so that future visiting engineers may get in touch with them. In all, discussions were held at seven research institutes, three educational establishments, two computing centres, and visits were made to four factories. In addition visits were made to an experimental laboratory of the Institute of Psychiatry, a nuclear power station and an administrative department of the Ukrainian Academy of Sciences.

The main purpose of the visit was to explore the work in automatic control, but the breadth of the subject and the country could scarcely allow this to be exhaustive. It was, however, possible to arrive at certain firm conclusions.

The team's conclusions

There is progress in the Soviet Union in most of the fields of industrial control, and analogue technique and digital computers are used as required. Although, possibly, this work is not far advanced in some fields, there is considerable activity in control in the steel industry, in telemetry, and in connexion with electric power systems with long transmission lines. This follows the special need of the Soviet Union, and it may be expected that in these fields they will advance rapidly. Although in some cases, work is being carried on by different institutes, the ease of publication and the central control seem to eliminate much of the overlapping. The publication of research work seems to replace as far as possible the facilities of interchange carried out in this country by the Institution of Electrical Engineers.

Organizations are being built up for further development in automatic control, and although these have only been in existence a few years, they are already beginning to make noticeable contributions. However, the potential contribution of these establishments, with their well equipped research organization and large number of engineers is very much greater. For this reason alone it would not be wise for engineers to neglect opportunities of keeping in touch with developments in the U.S.S.R.

Our observations in the education field confirmed that engineers necessary for the expansion of research effort are being trained. We were told that 83,000 stu-

* 'Automatic Control in Soviet Industry', available from The Hon. Sec., Group B, British Conference on Automation and Computation, c/o Institution of Electrical Engineers, Savoy Place, London, W.C.2.

dents graduated in engineering in 1958, and the centralized planning probably ensures that these engineers will be ready to meet the expansion of the laboratories. The connexion between teaching, research and industry is good, and with the Russians' larger research groups it must be expected that in a very short time the applications of automatic control in industry will overtake those in this country. Although the engineers will then be breaking new ground, there is little reason to suppose that their rapid rate of advance will be arrested.

These speculations lead to the conclusion that it will be increasingly useful to maintain communications with Soviet Russia in the field of automatic control. An excellent opportunity for this will occur at the Conference of the International Federation of Automatic Control to be held in Moscow in July 1960.

Other points in the report

The arrangements made for the visit are examined critically in the D.S.I.R. report, and suggestions are made to improve the information exchange during future visits. Two of the main points are discussed in more detail below: the report also includes notes on a discussion with Mr. S. Alexander of the U.S. Bureau of Standards, who was leading the second team of computer experts to visit the U.S.S.R. Professor A. Tustin was able to visit Warsaw on the return journey, and a report on his visit is also included. Finally, the report contains details of the work seen and discussed, so that those engineers wishing to follow up particular items may have some data on the present stage of development.

How the programme was arranged

Some weeks before the visit, members of the team were asked to give their special interests in the field of automatic control. From then on the arrangement of the programme was entirely in the hands of the Academy of Sciences. The list of institutes to be visited was received for the first time on the second day of the fourteen-day visit. At this stage it was very late to make changes to the programme, but this was done in some particular cases. We also found that it was expecting too much that our guides should have the detailed knowledge of the work carried out at each institute in our special subjects. In one institute, the director had arranged that a list of projects in hand was available in English, together with the names of the engineers and scientists involved. This was a tremendous help in ensuring that we made the best use of our time, and such information available some weeks before a possible visit would ensure that the time of both Russian and British engineers was used to the best effect.

Some changes in programme were made to suit our needs more exactly, and on a number of occasions, the team split into two so that two lines could be followed at once. On only one occasion was it necessary to cancel a visit. This involved the Electrosila plant in Leningrad, and the manager of the plant asked to be excused, since he had unexpectedly been asked to entertain a large delegation from China.

One is tempted to ask for a list of projects, and of the names of the engineers and scientists responsible, which would greatly facilitate exchange, but one has to bear in mind that anyone faced with preparing such a list for this country would also have his difficulties.

The language curtain

Experience during the visit seems to indicate that language is by far the most formidable curtain we have to encounter. During this exploratory visit only about one third of the time was usefully spent. Each visit had to be prefaced by a description of the work carried out by the institute, usually given by the director or assistant director, and this then had to be translated into English. It was then necessary to clear up various points arising in this translation, since it was difficult for even our first-rate interpreter to appreciate all the finer points of the special techniques discussed. Only after these preliminaries was it possible to get down to discussion of detail of the various projects involved, and so obtain the information given in the report. In all discussion of this kind the language barrier was a formidable obstacle. As soon as the formulae and diagrams came in, it was much easier to see the point of the discussion.

It is easily overlooked that a knowledge of the Russian alphabet is necessary, even to be sure of the names of the engineers present during a discussion. Also it is useful to learn both the printed and the written characters, since these are not all easily correlated. Where one of the Russian engineers was able to speak English fluently, the transmission of information was improved enormously, and we must pay tribute to the patience of the engineers throughout our visit, in their efforts to make sure that we understood their answers.

In future visits one might expect that discussion

The British team at Moscow University. Left to right, P. H. Hammond, A. J. Young, Professor Tustin, S. S. Carlisle, R. H. Tizard and A. Asbury

Professor B. S. Sotskov says good-bye to Professor Tustin at Moscow Airport. Golubenkov the interpreter looks on

would be on a narrower front, and this would make it much easier to obtain information once the source of the information has been found. Covering a very wide field made it difficult to deal with all the subjects that were of interest. Bearing in mind the other conclusions of the report, it is only possible to deduce that all engineers who wish to keep abreast of their field must learn at least to translate from Russian.

The principle of reciprocity

In the visits made it was clear that Professor Sotskov and the Institution of Automatics and Telemechanics had done their best to provide an exact counterpart for their own experience in this country. It must be understood that this principle of exact reciprocity will govern all discussion which takes place with the U.S.S.R. in technical matters. Only when both sides feel that they are gaining benefit can such exchanges be successful. With the different organization of industry in the two countries in mind, it must be expected that for future exchanges to be of benefit the field to be covered will have to be defined exactly. Only as engineers begin to know each other personally, and confidence grows, can the exchange of information become more complete.

Organization of research

It is not possible to visit the U.S.S.R. and see the well-equipped laboratories and high grade of personnel in them without considering their organization for research. In addition to research in the universities and the technical institutes, a whole field of endeavour is covered by the institutes under the Academy of Sciences of the U.S.S.R. This body enjoys high standing in the U.S.S.R. and is organized by the academicians themselves directly under the Council of Ministers. A parallel in this country would be research institutes directed and organized by professors who were members of the Royal Society, and financed by government grant. While universities in the U.S.S.R. restrict their attention to pure science, and applied science is the field of the technical institutes, the Academy of Science covers all fields. One of the major factors in the success of these research institutes, quite apart from finance, is the prestige enjoyed by the academicians, directors and professors. This prestige is also matched by financial reward, and it is not surprising that more than half of the university graduates in the U.S.S.R. graduate in science.

A further analogy may help to make this clear. The institutes of the Academy of Science are rather like universities, consisting entirely of post-graduate students directed by their professors. They also have very generous government finance. Truly a formidable combination.

Other impressions

Although the main purpose of our mission was technical, there is great interest in the Russian people themselves, and I make no apology for including some impressions of Russian life.

It must be remembered that the team were guests of the U.S.S.R. and as such were entertained in the Intourist Hotels throughout. On no occasion did the engineers visit the homes of their Russian counterparts, and it is impossible therefore to compare the intimate life of the Russian engineer with that of his equivalent in this country.

Our reception throughout was very cordial, and there is no question that the Russian engineers were only too anxious to discuss their technical problems with us. Although the expressions of the Russian desire for peace were made on formal occasions, our experience with the engineers we met left us in no doubt that these were quite sincere. In each of the three cities that we visited (Moscow, Leningrad and Kiev) there was ample evidence of flat building for work people. In Moscow particularly, the building effort was prodigious, and many blocks of flats were under construction, each with its crane.

In a very small number of years, Moscow will be rather a puzzle architecturally. Early Russian buildings have been restored, irrespective of their origin, and there has been intense building activity since 1919. This latter is in a style which reminds us of the late Victorian era, but it is built to last, and gives a characteristic appearance to the university, and Hotel Ukraine, and other large modern buildings. The large blocks of flats are somewhat rectangular and utilitarian, but doubtless furnish at minimum cost the housing so badly needed. Of the period between these two there will, however, appear to be little to show. In Russian eyes this can be only a small sacrifice for a city which has no traffic problems, and in which petrol stations of the type we know of in this country are conspicuously absent.

Moscow treated us kindly for the first few days, with temperatures around the seventies, but then suddenly betrayed us with a cold spell down below freezing. With a city at the same latitude as Edinburgh, this was perhaps not surprising for the end of May.

Finally, I must record that I was able to use my camera freely as I wished.

PART 1

Gas is being made, used and distributed in new ways, and these bring new problems. Modern methods of control help to solve them

Getting over problems in the gas industry

by **R. E. CLIFFORD**
London Research Station, Gas Council

MODERN TRENDS IN THE GAS INDUSTRY HAVE INTRODUCED a number of control and instrumentation problems. In addition to the traditional methods of producing gas from coal, various waste products from refineries and oil fields are now being used to supplement the supply. The tail gases previously 'flared' to waste are now collected, purified and piped at high pressure from several refineries to convenient gas-making stations, where they are 'reformed' in special plant to produce a gas suitable for district use. Another method that has been much publicized is the liquefaction of methane from South American oil fields and its transportation in special tankers to Britain, where it is converted back to gas and treated in the same way as the refinery gases. Liquefied petroleum gases such as butane are also being used in large quantities, with and without air dilution, as part of the basic supply and as peak-load reserve capacity (*1*).

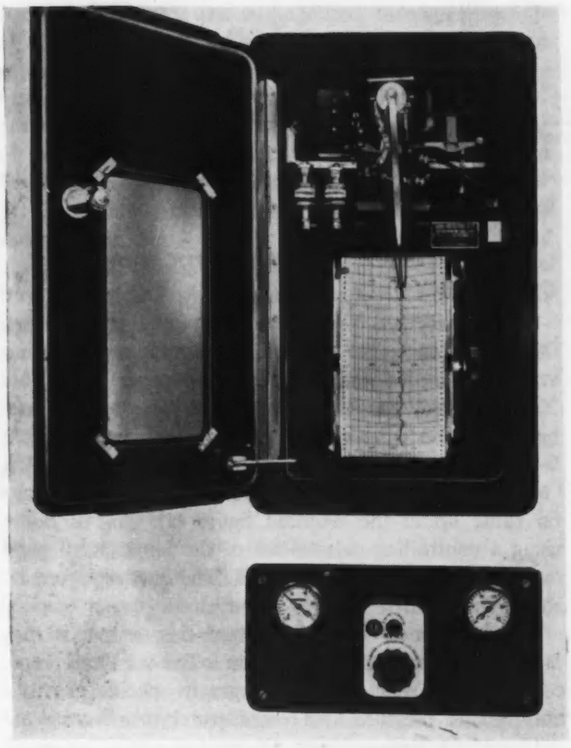

Fig. 1 Sigma-Kent controlling calorimeter

Other trends in the industry, such as the integration of supply systems and the expansion of large works at the expense of smaller uneconomical plants, have also enabled advantage to be taken of modern control methods.

The various control applications described in this article may be roughly divided into three sections. The first of these covers the control of gas quality, a general heading which includes calorific value, specific gravity, heat input and the properties of aerated flames. The second section covers the control of gas after combustion. By analysing the products it is possible to control the gas and air supplies to furnaces, etc., to give the most efficient performance. The last section describes the various methods of controlling the gas flame in appliances.

QUALITY SPECIFICATIONS

In order to understand the need for control of gas quality it is necessary to give a brief explanation of

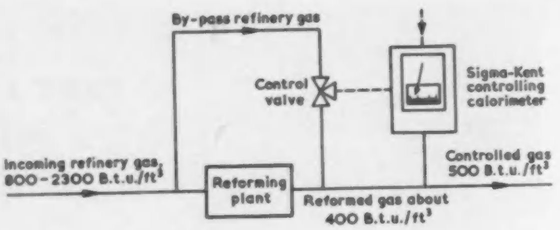

Fig 2 Control of calorific value of reformed refinery-gas

the quality limits, both legal and self-imposed, to which the industry has to conform.

Apart from regulations governing the purity of town gas, the basic legal requirement is that of calorific value, which has to be maintained to within 5% of a declared figure, usually between 400 and 500 B.t.u./ft³. But this is not the only variable that will affect the performance of gas-using appliances. Specific gravity changes will also alter the rate of heat input to burners. The actual rate is proportional to a function known as the *Wobbe index*, which is the calorific value divided by the square root of the specific gravity.

Fig. 3 Test layout for cone-height controller

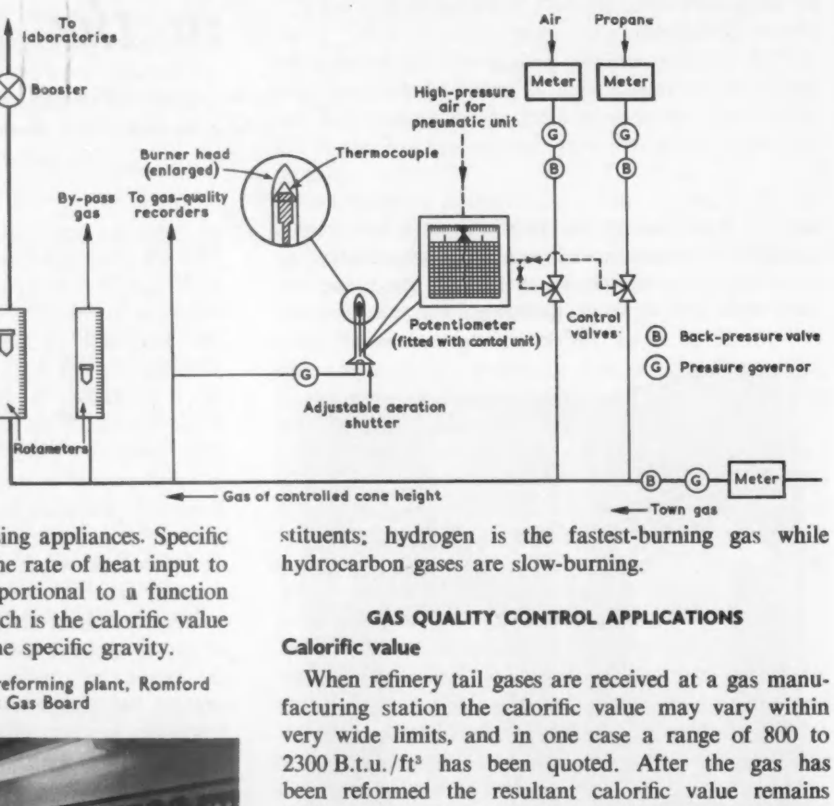

Fig. 4 Control room, refinery-gas reforming plant, Romford Works, North Thames Gas Board

The Wobbe index of the gas in this country varies from about 500 to 800, and this range has been divided into groups of about sixty units. Every gas supply system has been placed in one of these groups, and the output quality is kept within the required range. All appliances can be modified to work satisfactorily on the group gas available in any area by fitting the appropriate jets or injectors or adjustment of the pressure governors.

Another variable that is likely to affect the performance of gas equipment using aerated burners is the *aeration number*, which can be assessed by measuring the height of the inner cone of an aerated flame. It is based on an empirical scale of air-shutter openings on a standard burner, known as an *aeration test burner*. The aeration number is a property of town gas associated with changes in both the flame speed and Wobbe number. The flame speed of a gas varies with its constituents; hydrogen is the fastest-burning gas while hydrocarbon gases are slow-burning.

GAS QUALITY CONTROL APPLICATIONS

Calorific value

When refinery tail gases are received at a gas manufacturing station the calorific value may vary within very wide limits, and in one case a range of 800 to 2300 B.t.u./ft³ has been quoted. After the gas has been reformed the resultant calorific value remains fairly constant but is too low, and about 20% of the 'neat' refinery gas has to be added to bring the calorific value up to the required figure (*2*). This is done using a controlling calorimeter of the Sigma-Kent pattern (*3*),(*4*) as illustrated in Fig 1. The control layout is shown in Fig. 2.

The basic measuring element of this system is the Sigma recording calorimeter. Gas is fed (at a rate kept constant by correcting for changes in specific gravity, atmospheric pressure and temperature) to a burner at the base of a chimney consisting of two concentric steel tubes joined rigidly together at one end. The differen-

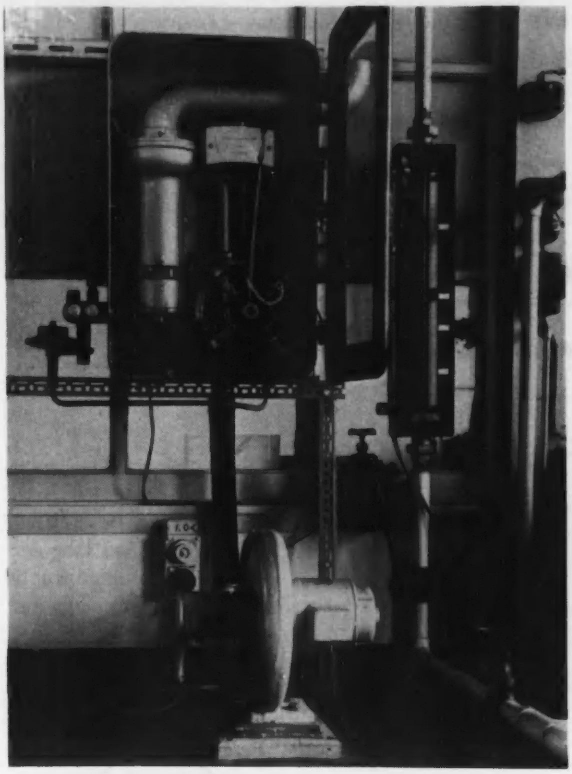

Fig. 5 Union quick-response Wobbe recorder

tial expansion of these tubes is a measure of the heat content of the gas, and is magnified, through a system of levers, to a pen marking a chart. Changes in specific gravity and atmospheric conditions are corrected by fitting a long vertical tube, after the gas-pressure governor, but before the flow-controlling orifice. The height of this tube is such that an increase in gas density will increase the pressure available at the orifice and exactly counterbalance the normal flow-reducing effect of such changes.

Inside the calorimeter is fitted a Kent MK.20 three-term control unit which is actuated by the movement of the pen away from any set control point. The great advantage of this device is that no electronic amplification of the measuring signal is necessary. Any movement of the pen away from the control setting on the recorder changes the air pressure at the control valve and automatically alters the position of the latter to keep correct the calorific value of the mixed gas.

Cone height and Wobbe number

Every gas appliance sold at gas showrooms in this country has to conform to several British Standards, and has to be approved by the Gas Council's laboratories at Watson House, Fulham. Apart from quality control tests there are special safety and combustion tests which every appliance has to pass. These performance tests are carried out on a standard gas with a Wobbe number of 730, but every appliance must also be able to function satisfactorily at high aeration and Wobbe numbers (with possibly incomplete combustion), and at a low aeration number (when aerated burners, such as those used in gas cookers, may tend to light back).

Preparation of these test gases has always been a problem, and three control systems have been used to produce gas mixtures of any required aeration or Wobbe number. Each of these systems is briefly described below.

Aeration number controller

This control system has been devised at Watson House, from an original idea of the South Eastern Gas Board (*5*), and has proved very satisfactory in practice. The test layout for this system is shown in Fig. 3. The basic sensing element is a thermocouple fitted axially in an aeration test burner. The tip of the thermocouple is placed at the top of the inner cone of unburnt gases. Any change in height of this cone will heat or cool the thermocouple, and the change in voltage output is recorded on a potentiometer. The movement of the recorder pen away from a set control point actuates a three-term pneumatic control unit, which opens or closes one of two diaphragm control valves, admitting air or propane to dilute or enrich the gas. By adjusting the air shutter of the aeration test burner, gas of any required cone-height or aeration value can be obtained.

Sigma-Kent Wobbe controller

This is an adaptation of the controlling calorimeter described earlier. No correction for specific gravity changes is required for Wobbe control, and the long compensating tube has been omitted. Any Wobbe number from 500 to 800 can be obtained with this controller by altering the control-point setting.

Union Wobbe controller

In this German device, which has been specially designed for quick response, a governed stream of gas is fed to an orifice and then to an aerated burner. A small blower supplies a large volume of air which passes a ring of thermocouple cold junctions and then mixes with the hot burnt gases. This mixture passes the hot junctions of the thermocouples and the increase in temperature, normally about 15°C, is recorded on a potentiometer directly in Wobbe-number units. For control a three-term pneumatic unit is fitted in the potentiometer, as in the cone-height controller. The controller is illustrated in Fig. 5.

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To be continued

PART 1 A few years of progress have made these authors completely confident in this automatic process-control instrument

Process control with infra-red gas-analysers

by **A. E. MARTIN**, D.SC., **A. M. REID**, A.M.BRIT.I.R.E. *and* **J. SMART**

Sir Howard Grubb, Parsons & Co. Ltd.

WITHIN THE LAST FEW YEARS THE INFRA-RED GAS-analyser has reached a high level of development and can now be used with confidence for automatic control. The range of such applications may vary from automatic regulation of ventilation in a vehicular tunnel to maintenance of the optimum operating conditions in a complex chemical plant. The required speed of operation will vary considerably from one application to another, being fairly rapid in the former and much less rapid in the latter case. The infra-red gas-analyser is merely a measuring device and provides a control signal with which the quantity to be measured can be maintained at a desired level.

PRINCIPLE OF OPERATION

The principle of the infra-red gas-analyser may be understood by referring to Fig. 1 in which the essential features of the instrument are shown. Radiation from the Nichrome heater *A* passes through the absorption tubes *B*, and thence to absorbing vessels *C* which are filled with the gas to be detected. A rotating shutter *S* allows light to pass intermittently, but simultaneously, through the tubes *B* and a heating effect is produced in each of the two chambers *C*. These receivers are partitioned off from one another by a thin metal diaphragm *D*, which, in combination with the closely adjacent insulated and perforated metal plate *E*, forms an electrical condenser. Any deformation of the thin diaphragm resulting from a pressure difference between the two receiving chambers causes a variation of capacitance.

If no absorption occurs in the tubes *B*, and the system is otherwise symmetrical, the heating effect in the two receiving chambers will be the same and no pressure difference between them will arise; but if now the gas to be detected is introduced into one of the tubes *B*, the energy balance is upset since radiation is absorbed by the gas before it can reach *C*. Consequently a pressure difference between the two cells *C* is set up each time the shutter *S* allows radiation to pass. The resulting capacitance changes are amplified electronically and a final indication is obtained on the output meter.

Any other gas also present in the sample will not affect the result unless it has absorption bands which overlap those of the gas being determined. The length of absorption tube to be used depends on the gas being estimated and the concentration range to be covered. The energy absorbed by a column of gas l cm long and containing concentration c of absorbing component is approximately $Elkc$, where E is the incident energy and k is an absorption constant, provided that kcl is small compared with unity. Thus at low concentrations it is advantageous to use long absorption paths, and the

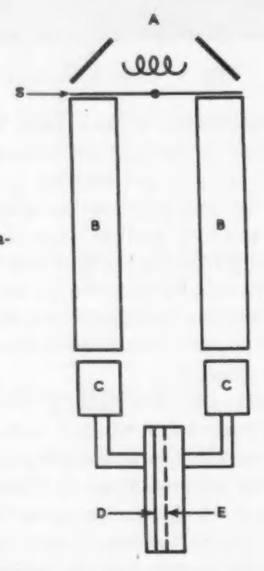


Fig. 1 Principle of infra-red gas-analyser

relation between the energy absorbed and c is reasonably linear. At higher concentrations the energy absorbed is $E(1-e^{-kcl})$ and the relation between energy absorbed and c departs greatly from linearity beyond about 25% absorption. Consequently when the absorption reaches this limit it is necessary to reduce the length of the absorption cell.

Dispersive analysers

This form of non-dispersive analyser is suitable for simple analyses such as carbon monoxide or dioxide in air, but with complex gas mixtures having overlapping

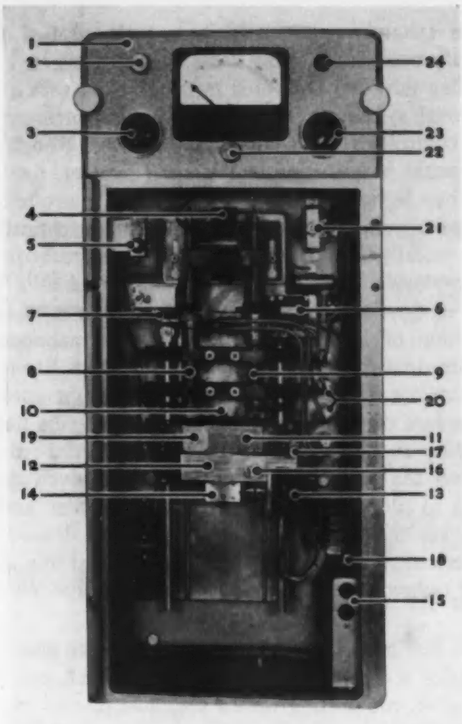


Fig. 2

1—amplifier; 2—sensitivity fine control; 3—sensitivity stepped switch; 4—detecting condenser; 5—microswitch (calibration); 6—calibrating device; 7—balancing shutter; 8—comparison tube; 9—analysis tube; 10—rotating shutter; 11—heating block; 12—reference generator; 13—shutter motor; 14—gearbox; 15—fuses; 16—phasing control; 17—adjustment for rotating shutter; 18—switch for shutter motor; 19—carbon dioxide absorbing capsule; 20—sample inlets; 21—pre-set potentiometer (recorder signal); 22—test point; 23—pilot lamp

absorption bands optical filtering methods are necessary. Some details of more elaborate analysers are given in a recent article (*1*). For the more difficult analytical problems an alternative to this type of analyser is a dispersive kind of instrument. In principle it is possible to use an infra-red spectrometer, although this is rather impractical since such instruments are expensive and intended primarily for laboratory use. However, greatly simplified spectrometers are becoming available and the clear-cut distinction between dispersive and non-dispersive analysers will surely disappear within a few years.

Confining ourselves in this article to non-dispersive instruments, we need to consider two main varieties. The first is the direct-deflexion type in which the output current due to absorption of infra-red radiation by the gas to be determined is indicated, recorded or used for control purposes. The second type is the self-balancing analyser, in which the out-of-balance signal is used to control the movement of a compensating shutter in the reference path so that equality is maintained between the two beams. The position of the shutter accordingly serves to measure the absorption of radiation by sample gas, and this instrument has the advantage over the direct-deflexion type of long-term stability, since the indication is to a considerable extent independent of changes in energy emitted by the infra-red source as well as variations in detector sensitivity and amplifier gain.

Factors which contribute to efficient operation of the latest analysers are: (1) use of a single enclosed infra-red source instead of the pair of sources as previously, eliminating a serious cause of zero drift; (2) employment of an entirely electronic form of synchronous rectification which greatly reduces sensitivity of the instrument to vibration; (3) use of fluorite throughout as a rigid and highly transparent window material; and (4) elimination of changes in signal due to mains variation.

Some idea of the construction of these instruments may be gained from Figs. 2 and 3.

SAMPLING PROBLEMS

One difficulty with the infra-red gas-analyser is that the sample must conform to certain standards of cleanliness if a satisfactory performance is to be maintained over long periods; the sample must also be sufficiently absorptive. Possible troubles and remedies are listed below.

FAULT	REMEDY
Gas wet	Use drier, e.g. activated alumina. Two units with built-in reactivators may be employed, with one unit in use while the other is being reactivated. Change-over can be made automatic.
Gas dusty	Use filters — sintered metal, ceramic, glass wool, etc. Wet scrubbing may be necessary in very difficult cases.
Gas corrosive	Use sample tube of suitable material or remove corrosive component by chemical means if permissible.
Gas carries volatile material which deposits in analysis tube	Remove volatile material by condensation, if permissible, and/or operate sample tube at elevated temperature.
Insufficient sensitivity.	Compress sample gas. Sensitivity is approximately proportional to pressure and, for example, at ten atmospheres full scale can be obtained for 10 p.p.m. by volume of carbon dioxide in air.

Some analysers are more vulnerable to dirty sample gas than others. The common type of instrument in which radiation is reflected down a highly polished tube is easily upset if dust or other material deposits on the walls of the tube. The null-balance instrument is affected just as seriously as the direct-deflexion type, but an analyser employing radiation in a parallel beam does not suffer to the same extent, and provided that the windows remain clean no trouble will arise from tube contamination.

Allowing for dirt

Sometimes the inevitability of tube contamination is accepted, and an attempt is made to allow for it by introducing a standardizing procedure at regular intervals. The sample tube may be filled with non-absorbing gas, a fixed obscuration introduced into the sample

beam, and the sensitivity adjusted until a standard deflexion is obtained. An ingenious method of overcoming the difficulty has been described by Liston, Andreatch and Beebe (*2*). In this instrument (Fig. 4) the radiations pass through the receiving chambers of the first detector into the receivers of a second detector. The sample gas is supposed to contain a wanted component P and an interfering component E. The first detector is charged with P and the second with E, and the detectors are connected in opposition so that in each path absorption in the second detector tends to neutralize the effect of absorption in the first. Thus in the left-hand path sensitivity of detector D_1 to E can be made equal to the sensitivity of D_2 to E so that this gas is ignored, while detector D_1 is more sensitive to P than is detector D_2 so that P is satisfactorily determined.

This particular instrument can be made largely independent of dirty tubes and windows in the sample path by the simple expedient of adding a non-interfering absorbing gas to detector D_2, e.g., carbon monoxide. With non-absorbing gas in the analysis cell the energy absorbed in detector D_2 is made equal to the energy absorbed in D_1, by addition of the appropriate quantity of carbon monoxide, so that any obscuration of the radiation by dirty windows or similar causes does not produce an output signal. The sensitivity will of course be reduced by a dirty analysis tube if the analyser is used as a direct-deflexion instrument, but this does not apply to the null-balance system.

CONTROL WITH AN INFRA-RED GAS-ANALYSER

In principle the problem of employing an infra-red gas-analyser in a control loop is much the same as for any other measuring instrument, such as a flow meter or temperature recorder, but of course the analyser is a more complex instrument and careful installation with adequate maintenance must be provided.

The advantages of quality control are obvious. Where

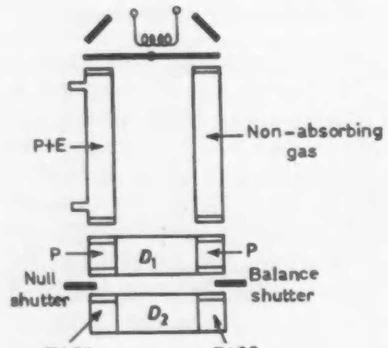


Fig. 4 Infra-red gas analyser with opposed detectors

a product must conform to a specification, the concentration of a possible contaminant may be determined continuously and control action taken automatically should the proportion rise unduly. This procedure is clearly an advance over less sophisticated methods, such as for example elaborate temperature control of distillation processes. In many cases the most effective way of using infra-red control is in conjunction with a conventional system employing temperature, pressure and flow control, or any combination of these. Rough control would be provided in the usual manner, fine control then being applied by the infra-red controller.

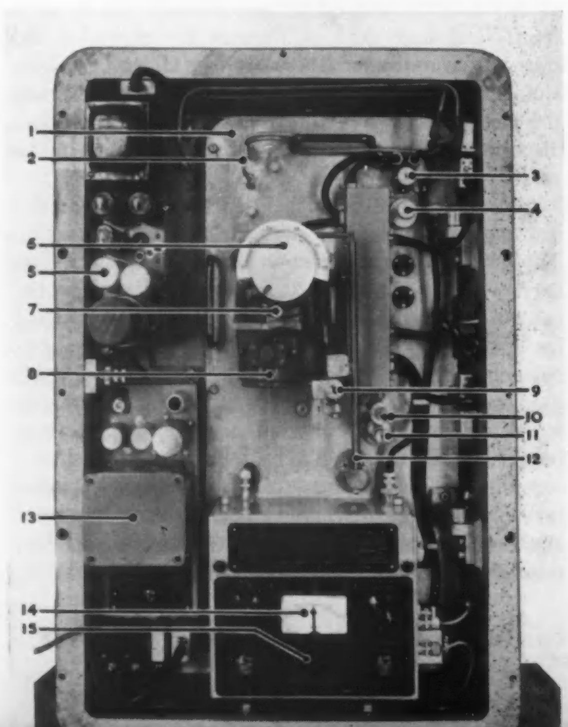
Control equipment may be operated pneumatically or electronically, or a combination of the two methods may be employed. Pneumatic control has reached a high level of development and has the advantages of ready operation of large control valves, easy maintenance, and freedom from flame-proofing difficulties. Electronic methods are still being developed and have the potential advantages of very precise control and extreme flexibility. Now that an advanced self-balancing infra-red gas-analyser has been developed it is a comparatively simple matter to add a three-term electronic controller, and the additional maintenance required is slight. If desired, the final electrical signal can readily be converted to a pneumatic output and the advantages of both systems realized.

The maximum d.c. output current from an electronic controller is usually in the range 5 to 15 mA and may be used in conjunction with a saturable reactor to provide appreciable a.c. power for the operation of solenoid valves, etc., or an electro-pneumatic power relay may be used to provide a 3–15 lb/in² air output to control pneumatically operated valves.

To be continued

Fig. 3

1—hinged optical bench; 2—sample inlets; 3—reference voltage phase adjustment; 4—adjustment for rotating sector; 5—servo amplifier; 6—cam and electrical output potentiometer; 7—electrical output zero adjustment; 8—servo motor; 9—sensitivity adjustment; 10—balance adjustment; 11—zero offsetter; 12—actuating arm for null shutter; 13—power unit; 14—test meter; 15—pre-amplifier with built-in test facilities



PART 2

Full integration of engine and helicopter requires transfer of the master engine control from the pilot to the rotor

The Napier Gazelle free turbine in the Westland Wessex lies at 35° to the horizontal

The helicopter turbine a power servo

by **A. W. MORLEY, PH.D., M.SC., F.R.AE.S.**

Royal Naval College, Greenwich

In Part 1, published last month, the principle of the power servo was explained and the helicopter rotor was considered as a power control. There followed a discussion of the power-off case, harmonic loads on the rotor, engine design, turbine temperature control, the time constant of the engine, difficulties with twin engines, simulator studies of load shedding, auto-operation with a failed engine, and engine control.

Fuel metering system

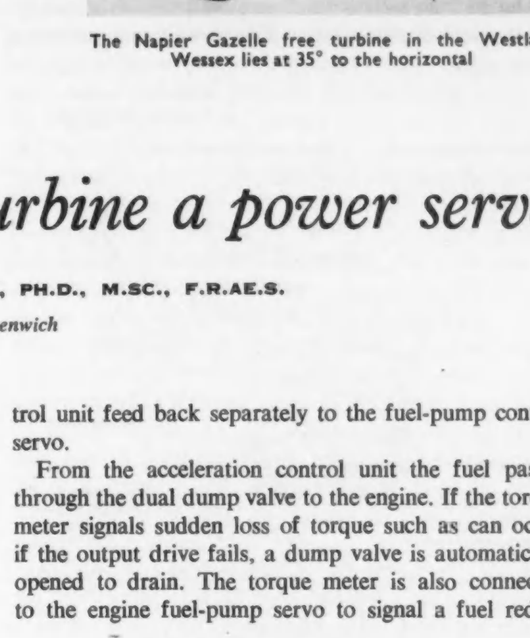
Fig. 4 shows the principle of the fuel control system of the Napier Gazelle free-turbine engine. Fig. 5 is a view showing the type of construction which the control follows, and indicates some of the principal parts. The barostat and fuel pressure regulator which is at the back in Fig. 5 is shown in section in Fig. 6. It is suitable for a single engine or a paired installation.

Fuel comes from the tanks via the booster pump (Fig. 4), through a filter with an icing detector and by-pass into the engine-driven fuel pump. The delivery of the fuel pump goes first to a pressure regulator for supplying the various servos in the system with constant-pressure fuel. The main flow passes on to the fuel-metering unit, where it is regulated according to the position of the engine throttle and compensated according to the air-intake pressure and temperature.

After leaving the main fuel-metering unit, the flow is trimmed by the speed governor and then by the acceleration control unit. The speed governor is regulated according to the signal received from the speed-signal generator. The speed governor and the acceleration control unit feed back separately to the fuel-pump control servo.

From the acceleration control unit the fuel passes through the dual dump valve to the engine. If the torque meter signals sudden loss of torque such as can occur if the output drive fails, a dump valve is automatically opened to drain. The torque meter is also connected to the engine fuel-pump servo to signal a fuel reduc-

Fig. 4 Elements of hydro-mechanical control



tion in case of excessive torque. A third duty of the torque meter is to send a signal to the power override servo of the second engine if sudden loss of torque occurs. This causes the second engine to operate on emergency power.

The emergency override is linked to the speed governor, maximum turbine-temperature control, and the torque meter, so that the settings of these three components are biased upwards in an emergency. The override servo is operated by a 'no-torque' signal received from the failed engine.

The turbine over-temperature unit signals direct to the engine fuel-pump servo. The speed-signal generator

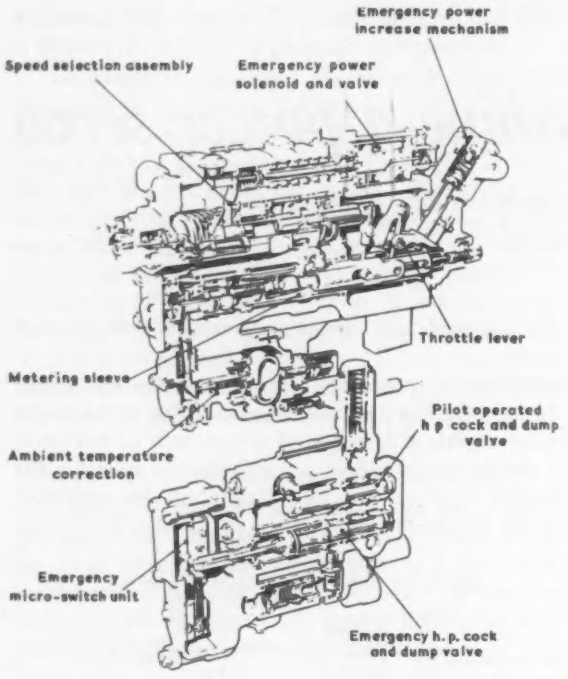


Fig. 5 Fuel-metering high-pressure shut-off cock and dump valve assembly

supplies the speed governor, and also provides a speed function for the compressor inlet-incidence control.

Speed governing function

A spring-loaded centrifugal governor can operate the pilot valve of a hydraulic servo. To minimize dynamic lags the pilot valve is reset continuously by some form of feedback as the servo moves. By introducing suitable elasticity and viscosity into the feedback, and by minimizing inertia effects, the governor can be made rapid in its response without introducing serious instabiity.

One application is seen in the engine governor used for the Westland Westminster helicopter. Here two Napier Eland fixed-turbine engines are connected through hydraulic clutches and gears to the one rotor drive. The governor arrangement (see Fig. 7) is an extension of the Lucas over-speed governor used in many

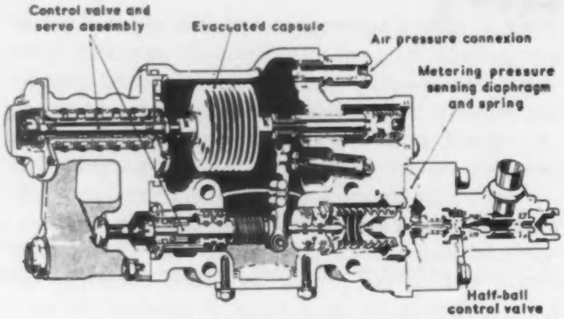
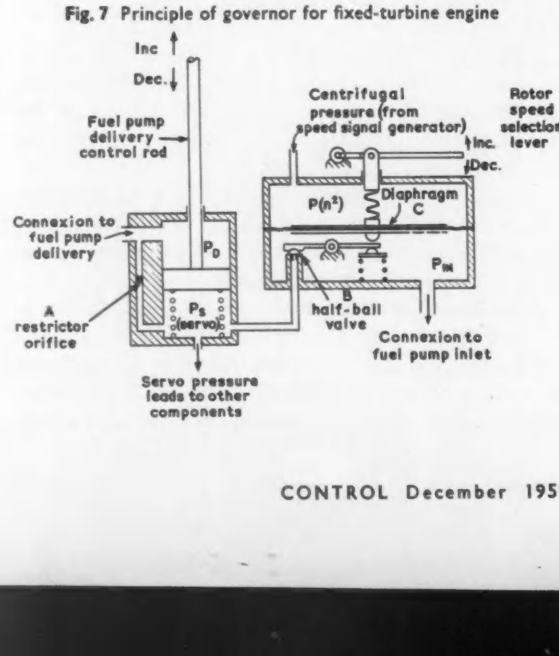


Fig. 6 Metering pressure controller

aero engines (*2*). The servo piston regulates the effective stroke of the fuel pump and moves so that the fuel supply is reduced if the delivery pressure P_D increases above requirements or the servo pressure P_S decreases. The latter pressure is maintained by a by-pass from the pump delivery through the small restrictor orifice *A* and is controlled by the leak through the half-ball valve *B*. A downward movement of the diaphragm *C* increases this leak and so reduces the servo pressure, which in turn reduces the fuel delivery to the engine. Acting on top of the diaphragm there is a force proportional to the centrifugal pressure $P(n^2)$, obtained from a speed-signal generator geared to engine speed. There is also a spring load on the diaphragm which may be varied manually according to the rotor speed required. An increase of the centrifugal pressure brought about by increased engine speed causes the half-ball valve to open, the servo pressure to fall and the pump stroke to decrease, thus correcting the increase in speed. The same effect is obtained if the diaphragm is loaded manually by the rotor-speed selection lever. This decreases the centrifugal pressure at which the diaphragm is balanced, so that the speed at which the engine is governed decreases.

The law of such a governor is smooth and approximates to one of the 'proportional-cum-integral' type. The change in the fuel flow following a change in selected speed is partly proportional to instantaneous speed and partly to the time integral of the difference

Fig. 7 Principle of governor for fixed-turbine engine



between instantaneous and selected speed. The time lag of the governor is reduced by reducing the first term, but there is more tendency towards over-swing and instability. As the result of long experience, it is possible to choose design constants which make the governing sufficiently sensitive and virtually dead beat. It has not been usual to give the speed governor authority over the full engine range because starting-up and various failure cases require special procedures. It is more usual to give it 'limited' authority, i.e. over the normal operating range only. Thus in the Westminster the engine control is arranged so that a fixed position of the engine-throttle-lever schedules a definite fuel flow somewhat in excess of the proper engine demand

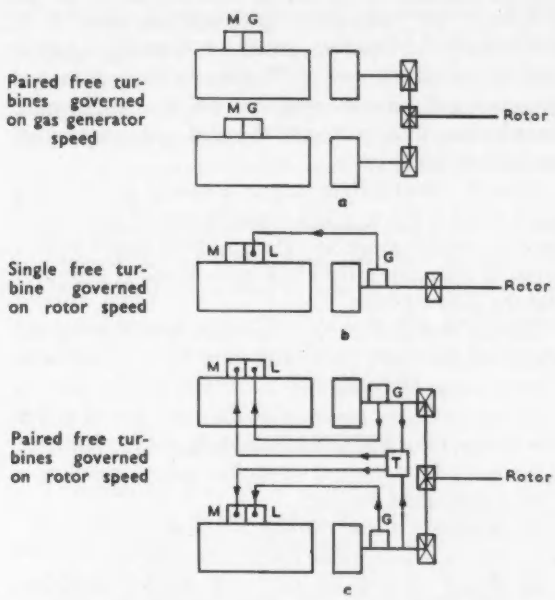


Fig. 8 Governing arrangement for a free-turbine engine

for the speed selected. This flow is then trimmed by the speed governor according to the setting of the rotor-speed selection lever. Over the flight operating range the lever is interlinked with the engine throttle control. If the engine throttle is left in a fixed position the rotor continues to run at constant speed and the power flows from the engine according to rotor demands. A manual torque-balance trim is incorporated to enable the load to be shared equally between the two engines.

Rotor-speed governing of the free-turbine engine

From the manufacturing point of view the form of speed governing built into the engine should be suitable for single or paired installations without modification. For this reason, although the speed governor is required on the rotor, it must be part of the engine, and it must be provided for on the output shaft of every engine, whether single or double, rotating clockwise or anti-clockwise. (See Fig. 8.)

For the single free-turbine engine the rotor-speed governor would be coupled to the metering unit on the gas generator, and the governor in this unit would be used for overspeed control only. In the case of paired free-turbine engines, the two output-shaft governors would signal to their respective metering units. The two gas generators would have individual top-speed limiters, and there would have to be a torque or speed balance across the two engines to ensure load sharing.

One possibility would be to combine the governors and torque balance units. Fig. 9 shows two diaphragms controlling the fuel pump servo, one carrying the rotor-speed signal-pressure plus a load set by a spring according to the rotor speed required. The other diaphragm acts as a speed limiter on the gas generator. The torque balance is operated by differential torque meter pressure. Any unbalance operates the fuel-pump servo of the engine carrying the greater load, and so opposes any error in speed selection between the governors.

An engine control specialist will see that the device in Fig. 9 does not satisfy requirements as it stands. For example, it does not follow that the torque balance unit would be capable of overriding the error due to disparity in the two governors, since this will depend on the characteristics (transfer functions) of the torque meters and governors. Also the torque balance unit is a shared part of a twin installation, whereas each engine should embody a similar unit. It also needs its authority to be limited to avoid single-engine failure, otherwise loss of the torque from one engine would cause the catastrophe of enforced shutting-down of the other. It would also have to be isolated for starting-up and single-engine check tests.

Another way of obtaining rotor speed regulation with the free-turbine engine is to make the engine virtually a fixed turbine by incorporating a centrifugal clutch, with a gear if necessary, between the free turbine and the gas generator. This would operate at all speeds above minimum cruising. The clutch would have the advantage that it would prevent run-away of the free turbine in some cases of drive failure.

Rotor power control with several engines

When a number of engines are connected to the same rotor drive, in the interest of better performance after single-engine failure, the chance of a control failure appears to be greater. This is because some of the problems are more complicated and can only be met by additions to the system.

As in the twin installation, it is necessary to provide means for equalizing the torques of the coupled engines, and the torque division must be accurate so that the full power of the helicopter can be brought to the nominal figure without any one engine becoming overloaded.

If many engines were geared to the rotor under rotor-speed control, no single engine would affect the load on the others, but since the number is not likely to exceed four, any change in the load on one will effect the loads on the others, and a sharing control is required to ensure that under critical conditions unde-

sirable inequalities are minimized. For example, in a four-engined installation, if the power of one engine were to fall by 30% when the aircraft was hovering, the other engines should sense a 10% reduction and each operate to restore 10%. It is of course questionable whether an engine losing 30% in output should be permitted to remain running. With certain forms of malfunctioning it would be better to shut it right down, in which case the other three engines would be called upon each to restore 33⅓% of normal hovering power.

Since flight safety will depend on the controls working correctly, it becomes important that all faults which could lead to serious malfunctioning can be sensed and isolated. For example, unwanted information from a failed engine must not affect the governing of the live engines. Thus a torque-balance control must not have the fault of the device shown in Fig. 9, which would cause it to shut down a live engine in striving to maintain torque balance with a failed engine. Similarly a low torque signal may be used to shut down a failed engine, but only if the torque is low by reason of a failure, not through pilot's selection.

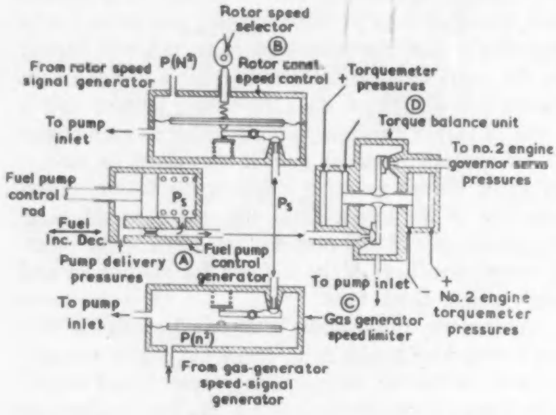


Fig. 9 Suggested device for governing coupled free-turbine engines

With multi-engined installations there will be more tendency to elaborate controls to ensure that no one fault can cause dangerous behaviour.

The basic faults against which safeguards are required are, incorrect speed and torque (or turbine temperature), and bad load-sharing. Over-power is a condition which may be taken care of by limiters. These limiters should have a characteristic which will avoid sudden tripping under a rapid transient, yet bring a faulty engine off-load as rapidly as possible. The detection of under-power has also to incorporate a delay function which will make it insensitive to transients. Failures in the operation of the load-balance control will be detected by big differences in the torques or speeds of the individual engines and operation of the over-under power sensers, but it may be necessary to provide further fault detectors which would isolate the faulty unit.

Conclusion

The full integration of the engine into the helicopter flight control system means taking the engine master control from the pilot and giving it to the rotor. The first requirement is a wide-authority governor on engine output speed which will maintain constant-speed operation of the rotor from low power to maximum power, including emergency operation, irrespective of rotor pitch, altitude and forward speeds. This governor must be fully integrated into the fuel metering system.

With the free-turbine engine any error in rotor-speed will be signalled to the engine control unit on the gas generator. The rotor-speed governor may need to be anticipatory, in order to provide a warning signal in time to the gas generator. The acceleration of the gas generator will be very rapid, and the governing system must ensure that transients of speed and temperature are held within bounds.

With the fixed-turbine engine a special governor for rotor speed is not required, since the engine-speed regulator is already available. The governor should have a range of operation over which rotor speed is kept constant by pilot selection.

Having provided for a rotor speed governor on the engine output shaft, the system must be examined with regard to the following: —

1. suitability of the governor as the controller of power flow to the rotor in normal and emergency conditions;
2. compatibility of paired or multi-engines, including—
   (a) independent starting,
   (b) bringing on load individually and together,
   (c) proper action under emergency load,
   (d) proper sharing of the load despite dissimilar characteristics between individual engines and their respective control systems;
3. autorotation and power-off landing.

A satisfactory scheme will be obtained when these requirements are met, according to the needs of the particular helicopter, with the minimum of complication in the engine control unit.

If development should bring too much control complication it will tend to stop multi-engine applications. An alternative trend would be to make the individual engine less dependent on accurate governing for safe operation. This would almost certainly dictate bigger power margins between maximum and normal and thus lose some of the advantage of the multi-engines.

Acknowledgment :
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End

Excellently organized, the International Congress and Exhibition of Laboratory Measurement and Automation Techniques in Chemistry was held in Basle last month. Here is a first-hand report

Ilmac

by **C. W. MUNDAY,**
The Distillers Co.

THE INTERNATIONAL CONGRESS AND EXHIBITION OF *Laboratory Measurement and Automation Techniques in Chemistry ('Ilmac') was held at Basle from November 10th to 15th, 1959. The Congress, the first of its kind ever held in Switzerland, was organized by the Association of Swiss Chemists, the Swiss Federation of Automatic Control, and the Swiss Industries Fair.*

The organization of the Congress was excellent and the layout of the Exhibition spacious, so that the exhibits could be studied in comfort. A pleasing feature was the fact that the staff at the stands were technically competent, and in general able to answer searching questions about their exhibits.

EXHIBITION

Two hundred and sixty-four firms from eleven countries had stands at the Exhibition, and fourteen thousand prospective customers from all parts of Europe attended it. There were only ten British exhibits, but a number of British firms were represented by Swiss agents. The British instrument industry would do well to note the massive German effort—about 30% of all the exhibitors.

The review which follows is necessarily selective, dealing with those aspects of measurement and control in the chemical industry which are relatively new.

GAS CHROMATOGRAPHY

This technique, suggested in Britain by Martin and Synge, has revolutionized chemical analysis, and at the present time it is probably the most important analytical method used in the chemical industry. As more and more chromatographs are installed in chemical plants, it is increasingly evident that gas chromatography is a powerful tool for process control in the chemical industry. This is reflected in the fact that more than half of the firms demonstrating gas chromatography equipment had plant instruments as well as laboratory models.

Carlo Erba, Milan

This firm, which has been working in the gas chromatography field for about five years, presented well-engineered laboratory and plant instruments. Their laboratory instrument (Fig. 1) is extremely versatile, and has a range of accessories that enables the specialist in gas chromatography to carry out almost any desired operation. The column may be operated at any temperature from zero to 200°C. There is provision for fraction collection, preparative work, column switching without disturbing temperature conditions, and a digital output integrator is available. A novel feature in this model is the micropipette with a mercury piston for the precision injection of small samples of liquid.

Fig. 1 The laboratory gas chromatograph from Carlo Erba was developed in an astonishingly short time

An externally mounted high-temperature accessory is available for work with column temperatures up to 400°C. Instead of detecting the separated gases in

the usual way, the separated components are oxidized in a heated microanalysis reactor, and the combustion products are passed through the katharometer after the elimination of water in a trap. The chromatogram is similar to the conventional trace, but the peak area is now proportional to the number of carbon atoms

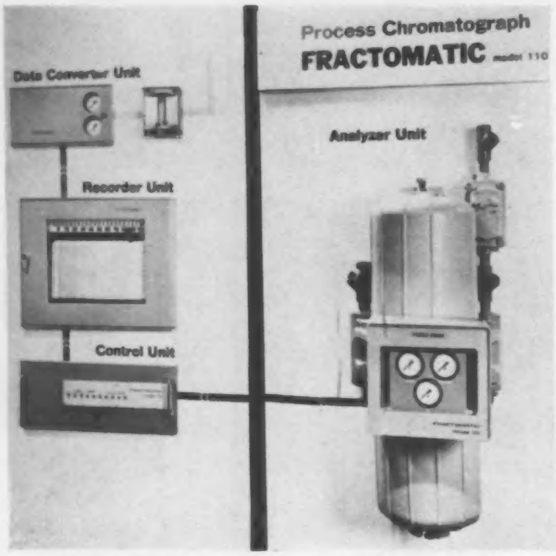


Fig. 2 Carlo Erba's process control gas chromatograph

present. The detection sensitivity for molecules of 10 to 12 carbon atoms is 200 times greater than for a system in which there is no combustion of molecules, provided that helium is used as a carrier gas. The increase in sensitivity is thirty times if nitrogen is used as the carrier gas. Some operators of chromatographs might consider the consequent destruction of the separated components a disadvantage, but this technique does get over the major problems that arise when complex organic molecules are passed through a katharometer at high temperature.

The process control gas chromatograph (Fractomatic model 110) is mounted in a cast aluminium housing suitable for use in hazardous atmospheres. The automatic gas sampling valve consists of minute pneumatically operated diaphragm valves. The sampling device contains no sliding surfaces and is stated to be completely leakproof. The programme controller, which may be mounted up to 600 ft from the analyser, converts the signal from the katharometer so that it can be presented in the usual bar graph form. A pneumatic control unit is being developed that will store the information from the bar graph pneumatically. Readings of any of four components recorded on the bar graph can then be used to control pneumatic valves in the conventional way. The instrument is shown in Fig. 2.

W. Ness, Zürich

A laboratory-type chromatograph was displayed. Two independent columns are employed to facilitate experimental work where it is required to change the column conditions frequently. The columns are flat glass spirals mounted in two cast-aluminium thermostatically-controlled housings. It is stated that the columns are readily packed by blowing the column material down the tubes pneumatically.

Siemens-Halske, Erlingen

This was the only German firm showing German-designed equipment, despite the large numbers of German firms present. The Siemens equipment is of all-glass construction except for the katharometer, and sadly conventional in conception.

Société pour la Diffusion d'Appareils de Mesure et de Controle, Lyon

The Ugine gas chromatograph is neatly engineered, with provision for external switching of columns, collection of fractions, and an operating temperature range of 50° to 250°C. The carrier gas used is hydrogen.

Pye, Cambridge

Pye demonstrated their well-known argon gas chromatograph and the katharometer instrument. They were the only British firm demonstrating in this field.

Perkin Elmer, Zürich

Laboratory and plant gas-chromatography equipment were shown by this firm. Photographs of the Golay capillary column system were on display, although this equipment is not yet commercially available. The discovery of capillary columns by M. J. E. Golay of Perkin Elmer is one of the most exciting of recent developments in gas chromatography. Golay found that if the inner wall of a capillary is covered with a thin film of the stationary phase, a long length of such capillary behaves like a normal chromatographic column with the exception that the separation process is much faster, and in fact it is now possible to have sample repetition times of the order of seconds. The volume of a typical column might be 160 mm^3. Consequently, much smaller samples have to be used which makes the problem of detection more difficult. Flame ionization techniques are, however, satisfactory, and it is understood that this method of detection will be used by Perkin Elmer. It is evident that for most practical purposes gas chromatography has become a continuous operation. Sample repetition times have already become so rapid that, at a recent demonstration by R. P. W. Scott in London, a gas-chromatograph trace was displayed on a cathode ray tube. This new development is still in its infancy, and many problems remain, but there is no doubt that capillary column techniques will have very useful applications in the control of chemical processes.

SPECTROSCOPY

Metrohm, Herisau

A new development in the field of spectroscopy is the spectropolarimeter exhibited by Metrohm. This Swiss instrument is the first of its type produced commercially in

Europe. Spectropolarimetry is a technique that has hitherto been confined to a few university research laboratories. Most of the equipment used has been adapted from commercial spectrometers, or built by the research worker. The problem in spectropolarimetry is to scan a solution of defined concentration with a beam of polarized monochromatic radiation, and to record the rotation of the polarized radiation caused by the sample at each wavelength.

In recent years spectropolarimetry has been used in the determination of the structure of complex organic molecules, and for the elucidation of problems in stereochemistry. The technique can also be used for the analysis of multi-component mixtures. When spectropolarimetry is used as an analytic technique, minute amounts of material can be determined because the rotary power reaches high values in the intermediate ultra-violet.

The Metrohm instrument consists of a prism monochromator, a self-balancing polarimeter and a recorder. A xenon lamp is used as a light source and is modulated by a disk at 600 c/s. The modulated light is then passed through the prism monochromator. Light from the exit slit passes through a self-balancing polarimeter which uses a photomultiplier as an error-sensing element. The position of the balancing analyser is transmitted electrically to a repeater-recorder with a 250 mm chart width. The paper drive of the recorder is mechanically coupled to the wavelength drive of the monochromator. The range of wavelengths covered is 2600 to 7000 A.U. The instrument is a prototype and it is expected that production models will be available in about one year's time.

Trub, Tauber, Zürich

Trub, Tauber of Zürich demonstrated the first high-resolution nuclear magnetic resonance instrument built in Switzerland. The equipment uses a permanent magnet for producing the magnetic field, and the sample is rotated at speeds up to 10,000 rev/min by an air turbine. The resolving power is one part in 10^8.

POLAROGRAPHY

Metrohm, Herisau

Metrohm showed a simple device which in effect speeds up the recording of polarograms by six times. The speed of mercury drop formation is increased mechanically so that drops are formed at rates of four to ten drops a second. In addition to speeding up the recording time, the increased drop speed results in a much smaller oscillation of the recording pen without the use of additional damping.

PHYSICOCHEMICAL GAS ANALYSIS

Wosthoff, Bochum

H. Wosthoff of Bochum showed a physicochemical gas analyser in which the component to be estimated in the gas is selectively absorbed, and the component is measured by the change in electrical conductivity of the solution before and after absorption. In the calibration of such equipment the problem arises of making accurate gas mixtures. This firm has designed a simple gas pump which will mix two gas streams in a given ratio to an accuracy of 0·1%. Five different concentrations of gas can be obtained by changing the gear ratio of the pumps.

MOISTURE DETERMINATION

Sina, Zürich

Sina of Zürich demonstrated their equi-hygroscope which measures the equilibrium moisture of materials and the relative humidity. Response time is less than 60 sec and the equipment can be manipulated by unskilled operators. It can also be used for the measurement of moisture in paper, linen, and granular solids. In this instrument a small measuring chamber is placed over the sample, and the atmosphere in the chamber is allowed to come to equilibrium with it. The resistance of a hygroscopic element, which forms an arm of a Wheatstone bridge, changes, and a simple servo-system rebalances the bridge. Motion of the balancing resistor is indicated on a dial calibrated in relative humidity. The temperature of the sample can be read immediately after making the humidity determination by turning a switch, and reading the temperature on an additional scale on the dial.

AUTOTITRATION AND CHEMICAL ANALYSERS

Technicon, U.S.A.

A number of autotitrators were on show, but all were batch-type instruments suitable for laboratory measurement. The only truly continuous chemical analyser demonstrated was that of Technicon.

The Technicon instrument continuously measures and compares on a recorder the level of concentration of a given component in the solution being tested, with a known concentration of that component in a standard solution.

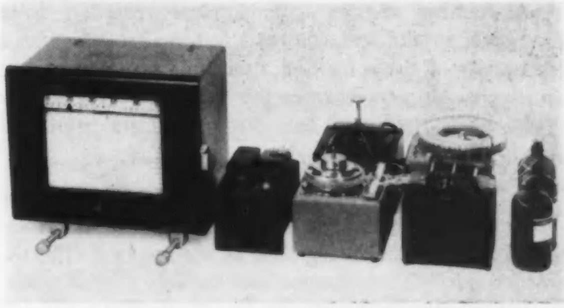


Fig. 3 The Technicon was the only truly continuous chemical analyser on display

Once the required experiment has been set up, the samples to be analysed are picked up, pumped along by a continuous proportioning pump, and mixed with a flowing stream of diluent. The diluted sample then moves through a dialyser where its diffusible constituents are separated and fed into a flowing reagent stream. Detection of the required component is accomplished in

various ways. The method demonstrated in fact used a colorimeter. The system has been used for difficult biological analyses, e.g., blood glucose, penicillin and streptomycin in reagent broths etc., but it can be adapted for most chemical determinations in aqueous media.

RECORDERS

Staub, Richtersville

A design of circular-chart recorder that might be said to be typically Swiss is the Elmes 12 recorder made by Staub and Co. This recorder is 3¾ in. square and 2·7 in. deep, and is claimed, with some justification, to be the smallest circular-chart recorder in the world. It is no larger than a conventional indicating meter and nine of these instruments can be packed into a 12 in. square. The chart diameter is 3·2 in. and the effective recording radius is about 1·2 in. A very clean record is obtained although no pen or ink is used. The record is made on a special type of paper by a pressure dotting pin, the pressure on the paper producing a red mark. The dotting frequency is once every 6 sec. The measuring element is a shock-proof and vibration-proof moving-coil or moving-iron system. The accuracy is $\pm 2{\cdot}5\%$ f.s.d. Three chart speeds are available, one revolution per day, week or month, and the desired speed can be selected by a sliding knob on the rear of the instrument. When used as a current recorder the sensitivity range is from 10 μA f.s. to 600 A (using an external shunt).

An alternative arrangement in which the chart revolution times are 1 h, 7 h or 30 h is also available. This is a neatly designed instrument and there must be many applications where the accuracy of this little recorder is quite adequate.

Sina, Zürich

A number of new potentiometer recorders were shown. Sina of Zürich showed a full-size recorder with a sensitivity of 1 mV f.s. and 1 sec for f.s.d. Rather surprisingly this firm charges the same price for single-point as for multipoint recorders up to eight points.

Philips, Zürich

Philips of Zürich showed a miniature potentiometer recorder with a minimum span of 5 mV, accuracy $\pm 0{\cdot}5\%$, and a balancing time of <1 sec f.s.d. The recorder is fully transistorized and requires a panel space of 144 × 144 mm.

CONTROL SYSTEMS

Honeywell, Zürich

Honeywell of Zürich displayed for the first time the ElectriK Tel-O-Set system for electrical process control. This system uses no line power connexions in the field-mounted devices, and there are only two wires between the devices and the control room. These two carry a maximum d.c. signal of 42 V 20 mA, and carry the measurement or control signal as well as the system power. The standard signal range used in the Tel-O-Set is 4 to 20 mA d.c. corresponding to the usual pneumatic signal of 3 to 15 lb/in². The system, therefore, has a live zero which has the advantage claimed for it, that it is a simple matter to distinguish between power failure and a zero signal. A range of suitable transducers makes the system completely compatible with existing pneumatic instruments. The system uses transistors throughout, the power transistors being manufactured by a Honeywell division.

The same basic idea is present in all the various transmitters, receivers, and final control elements. This is the use of a force balance system with feedback applied to improve the dynamic response. The system is outlined in Fig. 4.

The input force is applied to a pivoted beam. This changes the air-gap in a detector consisting of two pieces of ferrite, one of which is mounted on the pivoted beam and the other fixed to the chassis. The change in the air-gap changes the inductance in an oscillator circuit, which modulates the current in the circuit between 4 and 20 mA. A portion of the output current is fed back to a magnet unit producing on the beam a force equal and opposite to the input force. This re-balances the beam and limits its motion to about 1/1000 in. The field-mounted transmitters and transducers differ only

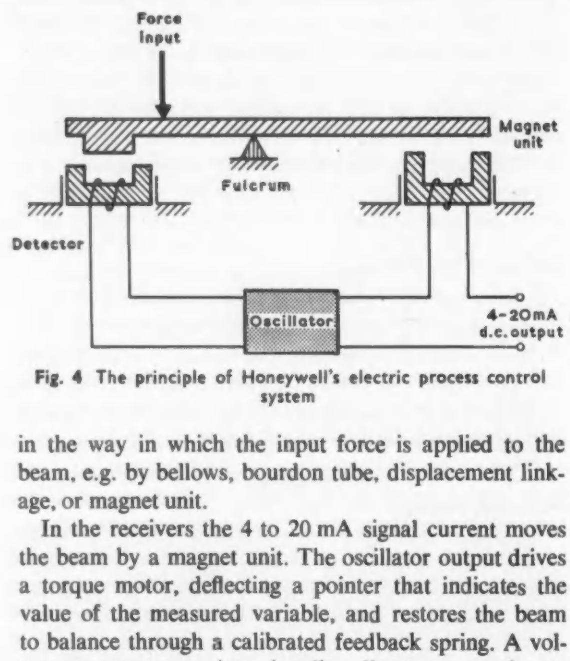


Fig. 4 The principle of Honeywell's electric process control system

in the way in which the input force is applied to the beam, e.g. by bellows, bourdon tube, displacement linkage, or magnet unit.

In the receivers the 4 to 20 mA signal current moves the beam by a magnet unit. The oscillator output drives a torque motor, deflecting a pointer that indicates the value of the measured variable, and restores the beam to balance through a calibrated feedback spring. A voltage-current transmitter handles direct current inputs from thermocouples, resistance thermometers, and process stream analysers, and is available in standard spans of 2·5 to 100 mV.

The electrical controllers in the Tel-O-Set provide the usual term or three-term control action.

ANALOGUE COMPUTERS

Güttinger, Niederteufen

One Swiss firm, Güttinger, makes specialized analogue computers for process control problems. One of

these computers is used in a German factory making steel tubes.

Güttinger also demonstrated an analogue computer, the Statistic, for the rapid calculation of the mean deviation and standard deviation of data fed into the machine. The data must first be divided into ten classes and the values for each class are inserted in the Statistic by push-button. Values for the standard deviation and the mean deviation are then read on a meter.

CONGRESS

Nearly one thousand two hundred members registered for the Congress, coming from all the countries of Europe, as well as the U.S.A. and the U.S.S.R. The first two days of the Congress were devoted to lectures on laboratory and measurement techniques used in the chemical industry. The last three days covered a wider field and dealt with automation in engineering, in the chemical and food industries, with the uses of data processing, and with the economics of automation.

Laboratory and measurement techniques

Problems of high frequency titration techniques were discussed by Professor Cruse. Milner of Harwell gave a clear survey of recent advances in polarography and explained the advantages of a.c. polarographs over the older established d.c. polarographs. Bates of the National Bureau of Standards discussed the attempts to define an irrational pH scale pointing out that the established experimental procedures for electrometric pH determinations are inconsistent with the fundamental definition of pH.

Professor Mecke of Freiburg surveyed the newer techniques of infra-red spectroscopy, with particular reference to the problem of measuring the absolute intensity of infra-red absorption bands. He also discussed the use of polarized infra-red radiation in the determination of the structure of crystalline materials.

Dr. N. Sheppard of Cambridge discussed the application of nuclear magnetic resonance to problems in organic and inorganic chemistry. He emphasized the fact that n.m.r. is a new physical method of considerable power for the qualitative determination of molecular structure, and can be used for the identification of the type and arrangements of functional groups in a molecule. The groups which can be detected in this way must contain elements with magnetic nuclei, e.g. hydrogen, fluorine, phosphorus, boron, etc. Oxygen and carbon do not give rise to spectra, and nitrogen spectra are usually weak, so that in organic chemistry the main emphasis has been on hydrogen resonances. In the hydrocarbon field it is usually possible to distinguish the different kinds of CH bonds. In particular, methyl groups are easily distinguished.

Dr. Hausser of the Max Planck Institute, Heidelberg, dealt with the chemical applications of electron spin resonance. This technique is a sensitive method for detecting paramagnetic substances, e.g. free radicals and paramagnetic metal complexes.

The uses of gas chromatography in the organic chemistry laboratory were discussed by Dr. Simon of the Technischen Hochschule, Zürich.

D. Mapper of Harwell gave a most interesting account of the uses of neutron activation analysis which is one of the most sensitive trace analysis techniques yet developed. It was learnt that the very low impurity levels required in silicon for transistors can only be achieved by control by neutron activation techniques.

Automatic control

K. Bechtinger of Polymetron gave a paper on the problems peculiar to the automatic control of chemical process by pH value and redox potential. Among the problems are distance-velocity lags in the control system, the non-linear relationship between the measured pH of the process stream and the rate of addition of the control fluid. Consequently, it is much easier to control pH in batch systems than in continuous flow systems.

Economic aspects

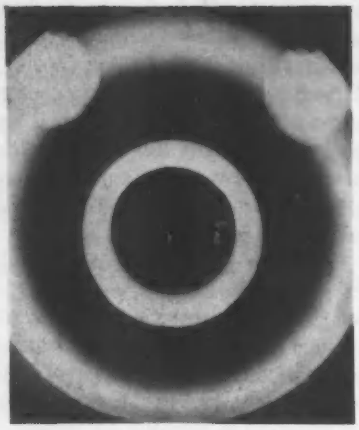
R. Khoblauch, of Honeywell Brown, Philadelphia, discussed economics and automation in the American chemical industry. He gave statistics to show that despite the fact that the total population of the U.S.A. is increasing, the number of men in the prime working force (i.e. those who actually produce the goods), would decrease in the next ten years. To maintain a rising standard of living, more goods would have to be produced by fewer people. One solution to this probblem is an increase in automation.

In the chemical industry, the trend is towards greater use of process stream analysers to control the quality of the product. This trend will increase and more process control analysers will be used in closed-loop applications. At the present time in the U.S.A. for every 100 to 200 process stream analysers used, only 12 were used in closed-loop control. He forecast that in the future the number of computers used for process control would increase, although not at the same rate as process analysers. It is estimated that at the present time the production of a plant had to be worth at least $3,500,000 per annum to justify the cost of a computer.

Data processing

The extensive use of quite sophisticated data handling systems in Swiss banks was described in a paper by E. Burgermeister, Director of the Schweizerische Kreditanstalt, Zürich.

Dr. W. Kaeslin of IBM, Zürich, discussed the uses of data handling equipment in production planning. His lecture was illustrated by references to the IBM factories. The computer stores information about the size of the order book, the delivery time of components, and evaluates the optimum stock level required in any given situation. When the stock falls below this level a signal is sent to the ordering department who take the decision to order.



PART B

ELECTRICAL TRANSDUCERS—9

Having introduced radiation sources and detectors in Part A, the author now describes some practical applications in industry

Nuclear radiation and X-rays

by **T. P. FLANAGAN, M.SC., A.INST.P., A.M.I.E.E.**
British Scientific Instrument Research Association

Last month, in Part A of this article, we described the kinds and sources of radiation, and also the various detectors that are employed. We went on to consider the measurement of physical parameters with such instruments, beginning with the gauging and control of thickness.

Fig. 6 shows a transmission system using a beta source to control the thickness of leathercloth, with an ionization chamber as detector. The method is a refinement of the basic system and uses two channels. One is the measuring channel, and the other is an identical standardizing channel which uses a standard absorber as a control reference for the measuring channel. The d.c. signals from each channel are backed off against one another and the control system operates on a deviation from balance.

For measurement of large thicknesses of heavy materials such as steel, gamma radiation is often used. Cobalt-60 is a typical source, which may be used to measure thicknesses up to about two inches of steel. Gamma backscatter gauges are also used to measure thickness when only one side of the material is accessible. Putman *et al.* (*3*) have described an elegant method which measures back-scattered gamma photons, but only those which have been scattered through 180°. The energy of such photons is accurately calculable from Compton scattering theory*; for example, the 180°-scattered radiation from Cobalt-60 1·17 MeV and 1·33 MeV gammas have photon energies of ·209 MeV and ·214 MeV. By means of a scintillation counter and a pulse-height analyser only those pulses are counted which correspond to these lower energies. This simplifies the problem of screening the detector from direct source radiation, but at the expense of complication in the electronic circuitry.

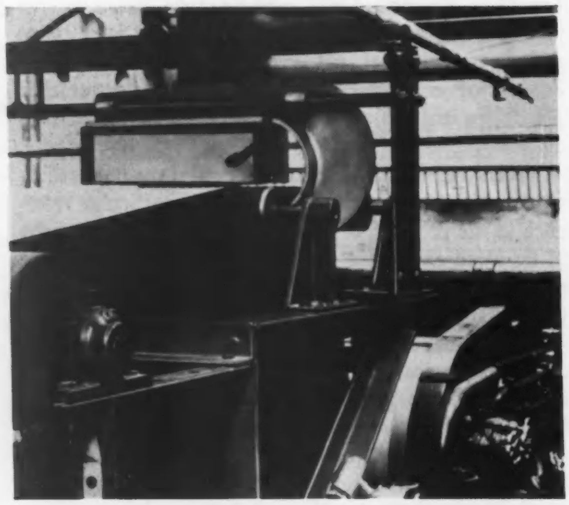


Fig. 6 Two Ekco heads, one on each side of the fabric, measure the thickness of p.v.c.-coated material at I.C.I. Leathercloth Division's works. The machine is a three-bowl calender

Alpha particles have been used to measure thicknesses in the region of 1 mg/cm². One such gauge measures the variation in the range of the particle in air after passing through the material (*4*). The decrease in range

**The Compton effect is an increase in the wavelength of X-rays or gamma rays scattered by electrons in, e.g., carbon atoms. Photons are deflected by collision with electrons. The energy lost by the photon, properly calculated, corresponds to the observed reduction in frequency and increase in wavelength.*

is then related to the mass per unit area of the material.

A somewhat ill-defined gap has existed between gauges which use high-energy betas and those using the low-energy gammas. This is because of the scarcity of long-lived high-specific-activity* gamma-emitters in the region of 100 keV energy. Thulium-170 has been used, but its short half-life and low yield of gammas and X-rays does not make it attractive. X-ray machines can be used, but they suffer from the drawback of high cost and maintenance problems. The gap now appears to have been closed by the introduction of the *Bremsstrahlung* gauge, which uses the X-radiation from a target bombarded with high-energy beta particles from a source with a long half-life. Strontium-90-yttrium-90 is used almost exclusively. Fig 7 shows a typical arrangement.

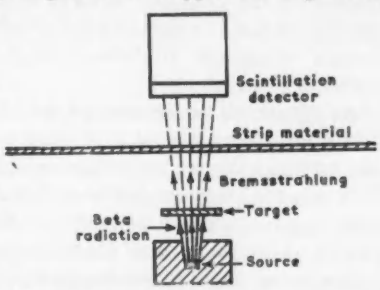


Fig. 7 Measuring thickness with Bremsstrahlung

Equipment of this type has been installed to measure the thickness of steel strip in a rolling mill. Fig. 8 shows such an installation.

Density measurement

This is closely allied to thickness measurement, using the same principle of absorption, measuring variation of absorption when the path length of the material is defined; for example, liquid in a pipe (*5*). For pipe measurements, path length of absorber is usually considerable and includes the pipe walls as a constant factor. Hence gamma radiation is used, caesium-137 or cobalt-60 being typical sources. Such a system is also obviously useful for detecting the interface between different liquids in a pipeline, providing they differ sufficiently in density.

Level detection and control

The absorption of radiation has been applied with success to the detection and control of liquid level in various situations (*6*). Fig. 9a shows the principle used. *A* is a gamma-radiation source the external radiation from which is confined by collimation to a narrow beam directed horizontally across the tank at the desired level. When no material is interposed between source and detector the signal (pulse count rate or d.c.) in the detector provides an electrical output which actuates the level-controlling mechanism. When the level rises so that the liquid just comes between source and detector, the radiation is partially absorbed, the decrease in signal acting to prevent any further increase in level. The output of the level detector can usually be arranged to indicate the level over a narrow range about the mean.

*The specific activity *of a radio-active substance is the rate of disintegration per unit quantity.*

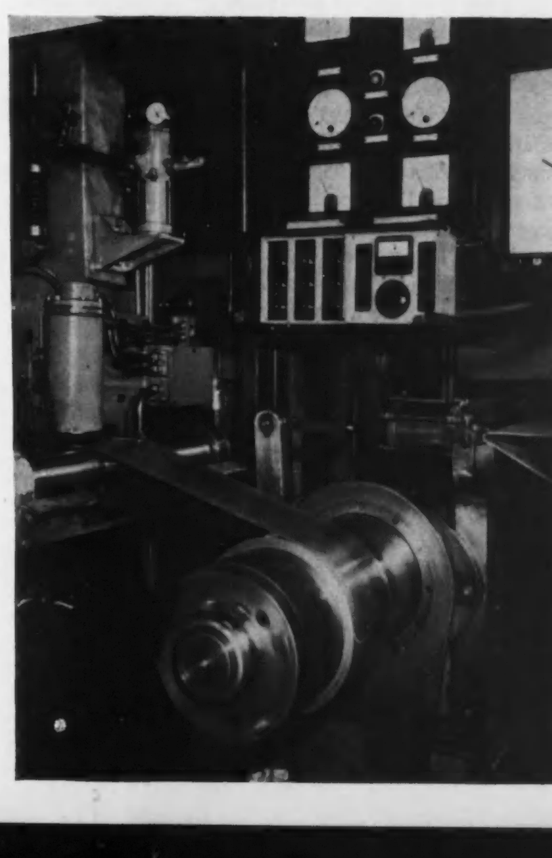
Fig. 8a Open-loop control on the gauge of rolled strip. Lights and a meter on the cabinet (right) indicate variations to the operator (left). The loop can be closed for automatic control, but the equipment is not shown in the picture

Over a wide range, however, it would probably be better to use a movable source and detector which is driven by a motor actuated by the detector output. In this way the position of the source-detector carriage would indicate the level.

Backscattering of gamma radiation may also be used for level detection. In this case the source and detector are mounted close to each other at the same level on the outside of the vessel, with suitable screening to prevent direct radiation from source to detector. Some of the radiation is scattered back from the vessel wall into the detector. When the liquid in the tank rises to the height of the source and detector, the backscattered radiation increases owing to the scattering from the liquid. This change in signal is used to operate the level control system.

The advantages of radiation level-controllers are that the level-detection system is completely external, so that the transducer is not subjected to the environmental condition prevailing inside the vessel. In some applica-

Fig. 8b A closer view of the source and the manual control unit



tions, such as the level-control of highly corrosive liquids or molten glass, such considerations are very important.

Moisture measurement

The slowing down of fast neutrons by hydrogen has been used to determine moisture in solids, particularly in large bulk materials (*7*). The principle is illustrated in Fig. 10. Fast neutrons from the source enter the surface of the material. The fraction which is thermalized in a reasonably short distance is proportional to the amount of hydrogen present. Some of these thermal neutrons diffuse back through the surface and are detected by the BF_3 proportional counter at A. Over a range from ·2 mg/cm^2 to 1 gm/cm^3 the count rate from the BF_3 counter is linearly related to moisture content, and the instrument is capable of detecting changes of ·005 gm/cm^3.

Flow measurement

The simplest example is the measurement of the time interval between injecting radio-active solution into the stream and the subsequent detection of activity at a known distance downstream. Water flow has been measured in this way by using sodium-24 in the form of sodium chloride solution. Turbulent flow is necessary to ensure that spreading of the volume of radio-active solution is not too great to smear out the burst of activity measured by the detector. Alternatively a dilution method can be used. Radio-active tracer solution of known activity per unit volume is injected at an accurately known rate into the flow. Samples of the liquid are taken downstream and the activity per unit volume is measured. The quantity $\frac{\text{tracer activity}}{\text{sample activity}} \times$ injection rate is the flow rate of the stream. This method is useful for the periodic measurement of flow in large flow systems (*8*).

A slight variant of the time difference method has been used to measure the catalyst flow rate in a circulating catalyst system (*9*). A few beads of catalyst containing zirconium-95 are introduced into the circulating system. Detectors at the top and bottom of the system indicate on a common recorder when the beads pass near. The recorder thus measures the time difference and hence the flow rate. Although the readings are not continuous, the method has been used satisfactorily to control the catalyst flow rate.

INDUSTRIAL INSPECTION

Radiography

The internal inspection of optically opaque objects by X-radiography has been standard practice for many years. In fact, for certain classes of equipment where casting or welding flaws may be hazardous or costly, official inspecting bodies and insurance underwriters have long insisted on X-ray inspection. The principle of radiography is that of differential absorption of the radiation by paths of different mean density. The density of blackening of a photographic plate placed behind

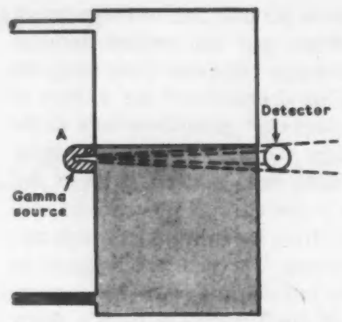


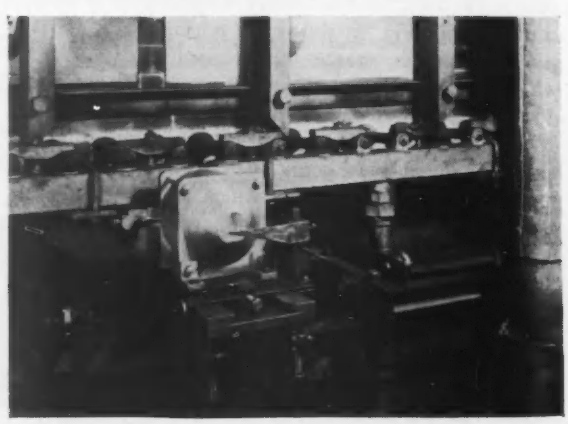
Fig. 9a Control of liquid level using a gamma source and detector

the test object is proportional to the intensity of radiation penetrating to the point under consideration, and the subsequently developed film yields valuable information on the existence of flaws in the material. The title illustration is a reproduction of a photograph taken from a radiograph. It shows filling holes and internal cracks in a cast wheel.

An important requirement of the radiation source is that it must approximate to a point, or the 'shadows' cast by flaws will not be sufficiently sharp for detection. It is usual to require that the source-film distance is more than a hundred times the source diameter, and greater than about five times the maximum object thickness, in order to resolve flaws the dimensions of which are not greater than 2% of the object thickness.

Up to the immediate post-war period, radiography was carried out by X-ray machines with the occasional use of radium gamma radiation. A wide range of radio-active fission products and pile-produced isotopes is now available for industrial use, and the suitability of some of these as gamma emitters has stimulated a big expansion in gamma radiography (*10*). The attraction of gamma radiography lies in its low cost relative to conventional X-ray equipment, particularly for high energies, and the possibility of applying radiography to parts which would otherwise be impossible to inspect by generators. For example, a source may be placed inside a small-bore pipe to check a circumferential weld completely in one exposure; this is done by surrounding the pipe with the photographic film. One of the dis-

Fig. 9b Installation for control of molten glass level in a feeder for bottle manufacture



advantages is that it is not possible to approach the intensity levels attainable with X-ray generators in the source sizes dictated by image resolution. This means that longer exposures are necessary. Also, with an X-ray generator the photon energy can readily be chosen by adjusting the generator voltage. With gamma radiography the user is limited to a range of radioactive isotopes which have sufficiently long half-lives and which possess the desired energy characteristics.

Table 2 lists the properties of four sources which are widely used in industry.

TABLE 2

ISOTOPE	HALF-LIFE	PHOTON ENERGY (MeV)	APPROX. STEEL THICKNESS PENETRATED
Cobalt-60	5·25 y	1·17 + 1·33	2–8 in.
Caesium-137	30 y	·667	¾–4 in.
Iridium-192	74·4 d	·610	½–2½ in.
Thulium-170	127 d	·084	Light alloys and non metals

It can be seen that a gap exists in the energy region of a few hundred keV. It may well be that beta emitters such as strontium-90, mixed in pellet form with a suitable target, will form *Bremsstrahlung* sources which might help to fill the gap. In the high-energy region, cobalt-60 and caesium-137 (also sodium-24, 1·4 and 2·8 MeV, for special applications where its short half-life of 15 hours does not weigh too heavily against its use) are doing work which could otherwise be done only by enormously expensive million-volt X-ray generators. Fig. 11 shows a typical technique of gamma radiography.

Leakage detection

An important test of newly laid water mains is that for leakage. Radio-active isotopes have been used successfully as an alternative to other systems (*8*). There are various methods which may be used; a common one for short runs of pipeline is to close all exits to the pipeline section, and to fill the section with water containing sodium-24 in the form of a soluble salt. Sodium-24 has the advantage of high-energy gamma radiation (1·4 and 2·8 MeV) with a reasonably short half-life (15

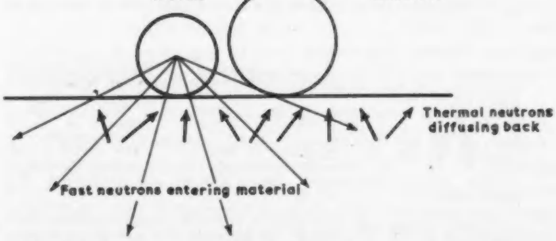


Fig. 10 Neutron-scattering method of measuring moisture content

hours) so that subsequent contamination quickly decays. The section is kept under pressure for a short time to allow some of the radio-active water to get away through leakage points, and then the section is flushed with normal water. An inspection of the ground with a gamma detector near the pipeline quickly identifies the point where radioactive water has leaked to the surrounding subsoil. A method suitable for pipe runs of some miles in length has been devised by Jefferson and Cameron (*11*). A fixed quantity of radio-active liquid is fed into the pipeline input, followed by the normal non-radio-active fluid. At any leakage point encountered along the run some of the radio-active liquid will be retained by the leakage path. A sealed Geiger counter and wire recorder in a suitable container are then sent along the pipe about half-mile behind the sample of radio-active liquid. As this floating probe comes to a leakage point it records the increased counting rate from the Geiger counter. Marker sources of cobalt-60 are placed at fixed intervals along the pipeline, giving regular peaks on the recorder, so that the position of a leakage point can be interpolated fairly accurately from the subsequent analysis of the recorder.

Fig. 11 A Co-60 source of gamma rays is here being used to inspect a circumferential weld in four-inch steel plate

Package monitors

A simplified form of level detector is used in quality control of filled packages. A collimated radiation source and detector are placed on opposite sides of a conveyor belt carrying the packages. The narrow beam is arranged to penetrate the package at the required filled level. If a package is not filled to this level the detector input increases and the package can automatically be removed from the conveyor belt. The stability requirements of the detector and its electronic apparatus are not great since they have only to detect a large change in radiation intensity.

ANALYSIS

X-ray fluorescence spectroscopy

This method of analysis (*12*) uses the principle of the excitation of characteristic X-rays by irradiating the sample with primary X-rays derived from an X-ray tube with a suitable target anode. The method is applicable to the quantitative determination of the concentration of a number of elements in a sample (by a scanning technique) or a continuous measurement of the concentration of a single element, this latter being of particular value in process control measurement.

Fig. 12 shows the principle of such a spectrometer. The primary X-rays from the tube fall on to the sample, which emits fluorescent characteristic X-rays. A fixed collimator selects some of these and passes them to a crystal of suitable characteristics for the wavelengths

under investigation. At particular angles of incidence of the X-rays upon the crystal the rays are selectively reflected, the particular angle being a measure of the wavelength and hence an identifier of the element, while the intensity of the reflected X-rays is a quantitative measure of the amount of element present. The rays reflected from the crystal spectrometer are detected by a suitable detector (Geiger, proportional counter or scintillation counter) the output counting rate of which is a measure of intensity. For a scanning system such as is used when measuring large numbers of elements, the detector has to move through twice the angle of the crystal, and this involves intricate mechanical design.

The accuracy of such a system is dependent upon its stability, which depends very much upon the stability of the e.h.t. voltage and current. To avoid the complication and cost of highly stabilized supplies, it is possible to use a standard sample in a double-channel system, one channel acting as a standardizing system. Variations in the counting rate in the standard channel, which can only be caused by instabilities of the system, are used to vary the counting time in the measuring channel, giving automatic compensation for drifts in the system.

Neutron activation analysis

This has proved to be a very powerful method of analysing trace impurities in highly pure materials (*13*). The material is irradiated in the thermal-neutron flux

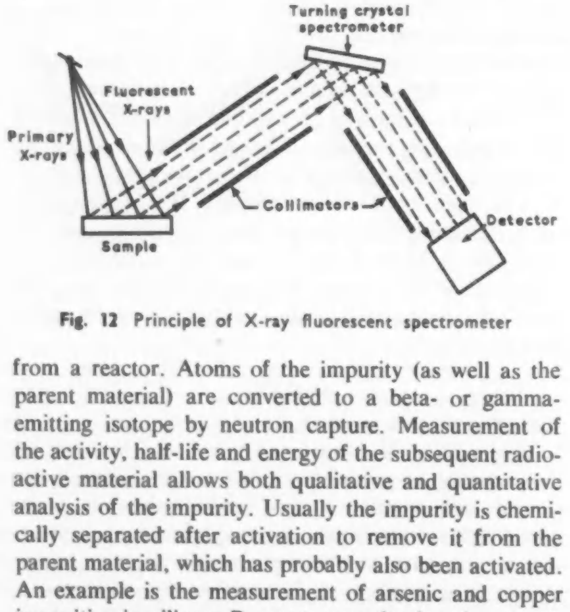


Fig. 12 Principle of X-ray fluorescent spectrometer

from a reactor. Atoms of the impurity (as well as the parent material) are converted to a beta- or gamma-emitting isotope by neutron capture. Measurement of the activity, half-life and energy of the subsequent radioactive material allows both qualitative and quantitative analysis of the impurity. Usually the impurity is chemically separated after activation to remove it from the parent material, which has probably also been activated. An example is the measurement of arsenic and copper impurities in silicon. By neutron activation the arsenic is converted to the radioactive isotope As-76, which emits gamma radiation of about 27 hours' half-life with an energy of ·57 MeV. The sample is dissolved, and an accurately known quantity of arsenic is added as a carrier of the radioactive trace. The arsenic is then chemically separated, and the measured activity allows the determination of the original arsenic impurity. These methods have made it possible to detect, in silicon, arsenic and copper impurities of one part in 10^{10}.

The argon v.p.c. detector

Vapour-phase chromotography is a system of analysing the constituents of a liquid (usually organic) by vaporizing a small sample, mixing it with a carrying gas and passing it through a 'chromatographic' column. This is packed with special materials which delay organic constituents by differing times owing to variations in adsorption coefficient between vapours. The time relationship of the emerging vapours permit identification, and the amount of vapour is a measure of the concentration in the original liquid. There are many forms of transducer which measure the vapour concentration, and a method based on beta ionization has been described by Lovelock (*14*). It is based on the fact that the rare gases argon, neon, etc., when exposed to ionizing radiations, contain an appreciable fraction of atoms which are ionized, and also a large number which are raised to an excited state but are not ionized. In many gases this excited state has a very short life, but in the case of the rare gases argon, helium, etc., the excited state has a long mean life, the so-called metastable state. If such excited atoms collide with other atoms or molecules, the ionization potential of which is lower than the excitation potential of the excited atom, energy is transferred and the molecule promptly becomes ionized. The ionization potentials of most organic vapours are lower than the excitation potential of argon gas, which has therefore been used as the carrier in a chromatographic column. The gas and vapour emerging from the column enter an ionization chamber which is measuring the ionization due to a beta source (Sr-90 foil). The steady level of ionization current represents pure argon. When a trace of organic vapour enters with the argon, the ionization current rises to a peak determined by the concentration. It is claimed that this device can detect as little as 2×10^{-12} moles of most organic substances.

Acknowledgment

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End

Pick-off

by *'UNCONTROLLED'*

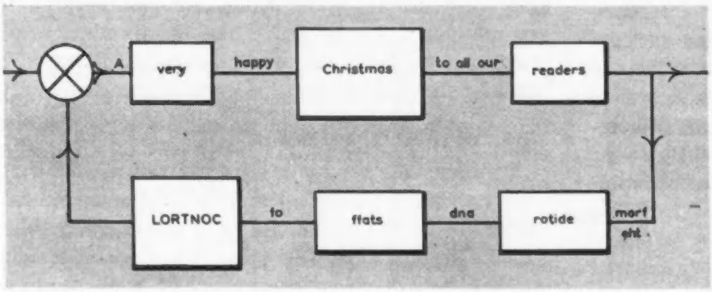
NEVER having met a bio-engineer, I was particularly keen at the recent Sima Convention to hear what was said by H. S. Wolff, a researcher at the Medical Research Council's Bio-engineering Laboratories. I thought that he made an excellent case for more attention by the instrument industry to the medical man's requirements. However, as Pritchard of Cambridge Instruments pointed out from the Chair, medical gear accounts for only about 0·3% of the total output of the instrument industry.

Wolff made the interesting suggestion that one's individual micro-climate might be varied by personal air-conditioning. Apparently, semi-conductor couples powered by an arrangement of solar cells, could be fitted to a suit, and the Peltier effect employed to cool the inside. The greater the amount of solar radiation falling on the solar cells, the higher would be the input to the junctions and the greater the Peltier cooling. The wearer of such a suit would have to stand in the shade if he felt too cold. I believe that American Westinghouse have received a contract from the U.S. Navy for bell-bottomed clothing of this kind, but they are rejecting solar power in favour of a more conventional battery.

Dr. Haigh, Director of the C.E.G.B.'s Berkeley Nuclear Laboratories, was another specially interesting speaker at the Sima Convention. Discussing 'isotopology,' he remarked that ten years ago the real money was thought to be in industrial control. That this is not so is well known; the question is, why?

IT makes me feel frustrated when more than one interesting event falls on the same date and I am forced to choose between them. But when near relatives like the Brit.I.R.E. and the Radio Industry Council make clashing arrangements, I begin to feel that the fates cannot bear the whole of the responsibility for my disappointment.

On 18th November the Radio Engineers held a six-paper symposium on electronic digitizing techniques. The final discussion of all the papers was scheduled to begin at about quarter past seven in the evening, but at seven o'clock the Radio Industry Council joined forces with the Electronic Engineering Association for their annual dinner at the Dorchester. A bit awkward for people like me, who wanted to enjoy both! (The two events are reported in *News round-up* elsewhere in this issue.)



WHEN I invite friends to my home I do not, while holding open the door, decline responsibility for any injury that they may suffer under my roof. (Let me here hasten to explain that I do not regard myself as unusually virtuous in this.) Yet apparently not all hosts will accept so lightly the hazards of hospitality.

Some weeks ago I was invited to join a Press visit to the works of a very big firm. On arriving with the rest of the party I was astonished when we were asked to sign papers that bound us not to hold the company responsible for any mishap during the visit! This behaviour would perhaps have seemed less odd if it had come after a request to be shown round the place, but with invited guests is struck a jarring note. The hospitality was in all other respects excellent, so I suspect that somebody at a fairly low administrative level made the mistake of working too closely to the book.

I am told that these scraps of paper do not in any case affect one's right at Common Law. But if that is so, why bother with them? Perhaps they are just another essay in popular psychology, and are designed to make the careless lay visitor less likely to dive into danger.

SPEAKING to a junior employee of one of our bigger electrical empires, I was struck by his remark that he felt no loyalty to the company as a whole because it was all too large. The loyalty that he did feel (and this he claimed to be quite strong) was toward those who ran the department in which he served.

I wonder whether he has a real point here? The sheer size of an organization can, it is true, make its lowest members feel so tiny that they become apathetic, but surely good management can put this right. Patriotism has been known to flourish in nations as well as in small tribes.

RELATIVISTS have enjoyed a brief spell of superiority to old-fashioned Newtonians, but progress accelerates logarithmically and yesterday's newcomers will not be enjoying their supremacy for long. I read in *The Times* that a Russian professor has evolved a new theory according to which time is a source of energy, producing power in the same way as flowing water. The professor has calculated that a certain new property of time, which he calls its 'course', is approximately seven hundred kilometres a second. This, as reported in *The Times,* is the professor's computation of the rate at which cause becomes effect. The 'course' of time, to make the point absolutely clear, 'has the properties of speed of revolution'.

This new theory comes from one who is stated to be a specialist on the moon. That body has long enjoyed credit for its striking effect on the mind. After reading this account I feel quite moon-struck myself.

Fourteenth I.S.A. Conference

A taste of some of the papers read this year in Chicago, and a quick glance at a few of the exhibits

THE FOURTEENTH ANNUAL 'INSTRUMENT-AUTOMATION' conference* of the Instrument Society of America was held this year in Chicago. The scope of the meeting was very wide, and we cannot do more here than select for mention a few of those papers that are likely to be more interesting to CONTROL readers.

Over 30% of the papers read to the conference dealt with process data handling and computer control. Some speakers suggested that data handling was important in its own right, and would be a lasting feature in the control landscape. Others held that it represented only a stage of transition on the road to complete computer control.

European instrumentation was analysed for the conference by Professor C. J. D. M. Verhagen of Delft University. He told his predominantly American audience that complex automation is not so attractive on the Continent as it is in the United States. This he ascribed to relatively low wages, short runs of product, consumers' dislike of standardized goods, and the relatively high cost of special devices. According to Verhagen there is a tendency for the European user to make his own instruments, even to the extent of computers. However, a mass market is in the offing in the six-country union, said Professor Verhagen, so automated mass-production would be stimulated in the future.

Taking advantage of non-linearity

Dr. Gibson (Purdue University) saw the newer and more exciting applications of non-linear control theory in the possibility of using non-linearities deliberately to synthesize a system better than its linear counterpart (*1*). He illustrated this by discussing three cases; an on-off relay, a 'dual-mode' (combined on-off and continuous) servo, and an adaptive or self-optimizing control.

Linear analysis

Bellman's method of handling variational problems can form the basis of a procedure for synthesizing a class of optimum controllers. Such a procedure was introduced by Lee (Minneapolis-Honeywell Regulator Co.) in a paper (*2*) in which he restricted himself to terminal control systems. He pointed out, however, that following and other systems could equally well be considered, and indicated a simple transformation that would convert one type of problem into another.

The Laplace transform is nowadays the standard mathematical device for analysing linear systems. But although this is so, said Professor Balise (Washington University), the real meaning of the transform is often not understood. In a review of some mathematical aspects of the transform (*3*) he attempted to bridge the gap between the engineer (with his preference for a physical model), and the rigour-loving mathematician. He began by introducing the Laplace transform as an extension of the Fourier integral, and approached the inversion integral in an unusual but, he suggested, more revealing way. His emphasis was on physical interpretation in order to clarify the theory for engineers.

Analogue computation of transfer functions

Transient or frequency response tests are sometimes impractical or uneconomic, and Dr. Milsum (National Research Council of Canada) described an analogue-computer technique for finding up to four unknown constants in a transfer function of surmised form (*4*). Accuracy within 1% or better can apparently be obtained in a few minutes. Either the transient or the frequency response can of course be derived from the transfer function when it has been determined.

Reactors chemical and nuclear

Instrumentation now in use to investigate the dynamic response of chemical reactors was described in a paper (*5*) by Pauls, Olt, Romano and Stanton (Monsanto Chemical Co.). Two laboratory models are being studied, both of plants for single-phase liquid reactions. The interesting variables are temperature, flow, and composition, and the strictest requirements in the instrumentation relate to drift, sensitivity, accuracy, frequency response, and noise. Mechanical oscillators generate 0·0001 to 1 c/s for frequency-response testing.

According to Hall and Bilbao (Atomics International), the application of systems engineering techniques to the automation of an experimental sodium-cooled nuclear reactor resulted in a design employing a maximum of conventional steam-plant equipment (*6*). The authors described the control system as one designed to integrate automatically the operations of the reactor, heat-transfer system, and electric generators. The plant is compatible with area load frequency control in modern interconnected distribution systems. The paper included a comparison of the responses of nuclear and fossil-fuelled stations to load changes.

Control gives quality to pulp

Some of the problems of producing Kraft pulp were described by Trevebaugh (Kamyr, Inc.). According to this speaker, the system required was one of the few

**Held in the Chicago International Amphitheatre, 20–25 September, 1959*

where controls made the difference between average and high quality (7). To reduce costs and make the product more nearly uniform, the manufacturer had to make his plant as nearly automatic as possible. All the critical controls were mounted on a panel from which a single operator could run the entire system.

Hydraulics for fast control

Three hydraulic control systems for rolling mills were described by Blain (Institut de Recherches de la Sidérurgie, France). Because of the inertia of the motor and drive, regulating systems acting on the screw-down are slow in producing results. Therefore, the author argued, to obtain a rapid response it seems desirable to use hydraulic devices (*8*). He illustrated his case by showing how hydraulic servos had been used to govern the distance between the rolls in a hot-strip reversing mill, a 33-in. blooming mill, and a four-high cold-strip mill. These applications had shown that hydraulic devices could be used without any practical difficulties, and he was convinced that much improvement was still possible.

Another champion of the hydraulic servo was Marshall (Vickers Inc.), who emphasized that accuracy is determined by the ability of the driving members to accelerate and produce sufficient torque rapidly enough to correct errors. In his paper (9) he showed some of the characteristics of hydraulic drives and indicated a few of the design techniques that might be used in applying them. Hydraulic components, he pointed out, are inherently capable of high torque and force 'per package size,' and should therefore be chosen where precise control is required.

Pneumatics are not dead yet . . .

Recent developments of pneumatic actuators were reported by Holben (Conoflow Corp.). In his talk (*10*) he referred to efforts by actuator manufacturers to improve the methods of producing restoring forces. Reversing relays, four-way valves, amplifiers and boosters, he declared, had greatly advanced the art. The all-pneumatic servo offered potentialities—still not exploited — for the dependable provision of accuracy, higher power, and increased speed. As design engineers became more familiar with servo theory and its application to pneumatic controllers, higher performance would be achieved. No longer was the final control element necessarily the slowest in the process.

. . . but the thermal-electric actuator has been born

Schweitzer (The Swartwout Co.) asserted that the overall increase in electronic instrumentation had unquestionably brought about a greater need for an entirely different electric valve-actuator. His answer (*11*) was the 'thermo-drive' actuator*, in which a liquid is kept boiling by an electrical resistance heater. A condenser controls the pressure of the vapour, and thus the movement of a spring-loaded diaphragm. Flow in the condenser is regulated by an electrically operated valve to which the output signal of the controller is fed. The continuous flow of heat into the device, and the continuously regulated outflow of heat, provide a sensitive system that can give a good response, and in his rather lyrical conclusion Schweitzer foresaw an increasing number of applications of electronic process control with the aid of 'this little warm stainless steel ribbon that makes large controllable forces out of little bubbles.'

Looking after viscosity

Although our wives have an intuitive feeling for viscosity in the kitchen, said Minard (Brookfield Engineering Laboratories Inc.), it has been only recently that *continuous* measurement of this dimension has been employed in analysis. His 'competitive fires having been banked temporarily', the speaker reviewed three different proprietary types of viscometer (*12*). He went on to illustrate the importance of viscometry in the manufacture of Portland cement and glass.

Also interested in the viscosity of glass were Straight and Huffman (Hagan Chemicals & Controls and Pittsburgh Plate Glass Co.). Difficult problems cannot necessarily be solved by writing rigid specifications, they said, and co-operation between process and control engineers is a better method; there are often points that cannot be seen by either alone, but that show up readily when both work together. The authors went on to describe a process control system that had been developed collaboratively in this way (*13*). Continuous-fibre glass yarn is made by drawing strands from molten glass flowing through holes in an electrically heated platinum bush. The viscosity changes very rapidly with temperature, and the length per unit weight of yarn changes about 1%/°F. An integrated system of electronic and magnetic components is used in the controller described, and the process characteristics are found to be such that proportional plus rate control, with a very little reset, is required. The reported performance is $0{\cdot}2\mu V/^{\circ}F$ temperature transient, 10s for 15°F transient response, and $\pm\frac{1}{8}$ to $\pm\frac{1}{4}$°F steady-state accuracy.

Varying speed

Despins (Reliance Electric & Engineering Co.) told the conference of a 'new final control element', a pneumatic variable-speed drive, and went on to say that in recent years it had found a steadily increasing number of applications in process control (*14*). The element consists of an electro-mechanical variable-speed drive that can be coupled to pumps, blowers and conveyors. The belt transmission includes sheaves of adjustable pitch diameter, and these are controlled by pneumatic servo. A typical drive operates from a signal of 3 to 15 lb/in^2 and produces an output speed directly proportional to the signal. The authors claimed that the frequency response of the element was suitable for open- and closed-loop control where less than 60 h.p. and a speed range less than 10: 1 were required.

*See CONTROL for October, page 91

Ward Leonard drives with magnetic amplifier excitation are rugged and easily maintained, said Traweek (The Louis Allis Co.), but they need a relatively large power for control and are limited in some desirable functions (*15*). He argued that, while the disadvantages could be overcome by using more stages of magnetic amplifiers to increase gain, this was not economic, and that to combine the ruggedness of magnetic amplifier control with the flexibility of electronic control a complete line of d.c. Ward Leonard drives with transistorized generator field control had been developed. The transistor control was used as a pre-amplifier for a magnetic amplifier that excited the field.

Controlling and measuring flow

Some of the major problems of flow metering were defined in a paper by Stoll (Taylor Inst. Cos.). He pointed out that 70% or more of industrial process instrumentation is concerned with flow measurement (*16*).

Isobe and Hattori (Tokyo University and Hokushin Electric Works) proposed a pulsating gas flow-meter, which they claimed had been developed into a practical instrument for flow control (*17*).

The application of turbine flow-meters to cryogenic liquid measurements was discussed by Professor Grey (Princeton University) in a paper in which he paid particular attention to questions of accuracy and sources of error (*18*). He gave simple criteria for the elimination of cavitation and compressibility deviations, and calculated the theoretical calibration error due to meter contraction at low temperatures. He also showed that his rough predictions of viscosity effects were substantiated by preliminary experimental data.

Design studies had produced butterfly valves for control under severe service conditions, said Bestmann (Fisher Governor Co.), and such valves should no longer be overlooked. They had the advantages of low first and maintenance costs, and were adaptable for most control applications (*19*).

The fundamental aspects of force balance and motion balance in the design and application of electronic flow transmitters were discussed by Dr. Kronmueller (Siemens & Halske A.G., Germany). In his paper (*20*) he dealt with errors due to temperature and overload, provision for range-changing, and so on. He concluded that force-balance transmitters are preferable for small static pressures and ranges, but that for higher pressures and ranges there are advantages to motion balance.

The current problem, as seen by Kogen (G.P.E. Controls, Inc.), was to build flow transmitting equipment that would allow maximum use of computers (*21*). The addition of the computer to automatic control systems had added an entire new range of problems to flow measurement. Some of the more important factors to be considered when flow signals were fed directly to a computer were: 1. ease of entry to the computer; 2. noise in the transmission signal; 3. accuracy of measurement; 4. dynamic response; 5. range of measurement; 6. the possibility of linear flow signals.

An all-electric gas-flow computer was discussed by Levis (Minneapolis-Honeywell Regulator Co.). This consisted basically of a differential pressure transmitter, an absolute pressure transducer, an analogue computing circuit, and a potentiometric receiver, and it measured automatically and continuously the mass flow of the gas. The speaker claimed that the system could be a useful tool in many industries for such operations as accounting, dispatch, and control (*22*).

The Exhibition

The conference was run in conjunction with an exhibition, of which it is unfortunately impossible to give anything like a full account here.

Among the more interesting products was a new General Electric flow meter. A fixed turbine is driven by the stream, and the torque is proportional to the mass flow. The torque is integrated and transferred by gyro precession to a cyclometer, and this registers the total mass that has passed.

For continuous stream analysis, there was a photometric instrument by Shell. This relies on radiation with alternately different wavelength following the same optical path. Concentrations between one and ten parts per million can be handled.

An automatic viscosity controller was shown by the Norcross Corporation. A freely falling liquid is timed in its descent through a tubular orifice. A throttling valve is operated by the electrical output, and adds solvent to correct the viscosity of the process liquid. 'High' and 'low' alarms can be provided.

The Hagan analogue-computer control system was shown. This consists of input transducers, an analogue control computer with patchboard and operational magnetic amplifiers, a remote control station, and final controlling elements.

A shaft position encoder was demonstrated by the Telechrome Manufacturing Corporation. This stores as well as converts signals from analogue to digital form. The encoding rate is 20,000 per second, with a read-out time of ·05 second.

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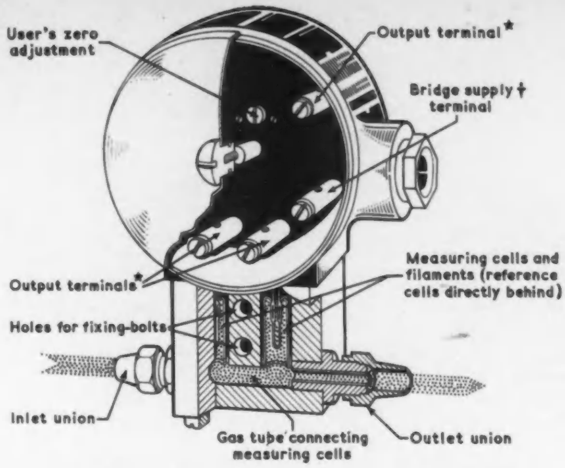

*total of 4, 2 for indicator, 2 for recorder †other terminal hidden by cap

courtesy Cambridge Instrument Co. Ltd.

Fig. 1 A section through an instrument working on thermal conductivity

CONTROL 14 SURVEY

OXYGEN ANALYSERS

by **G. M. E. WILLIAMS**, B.SC., A.M.I.E.E.

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THE MEASUREMENT OF THE PROPORTION of oxygen in a mixture of gases dates from the eighteenth century when Lavoisier conducted his famous experiments on air. This work established his as one of the fathers of modern chemistry, and was the starting point for present techniques in the control of combustion and other oxidization processes.

The process of combustion of fuels in air is still, after three centuries, incompletely understood. Improved chemical process and furnace operation has been developed based on measurement of some of the many variables in the processes, and among these partial chemical analysis of the gaseous products of combustion has been for long a familiar yard-stick. These observations or measurements have been, and still are made, for example, on small samples of the flue gas with apparatus such as that of Orsat, or on instruments which automatically ingest and then analyse such samples, indicating the results on a strip-chart record.

Scope of the survey

This survey is solely concerned with instruments which can measure the oxygen content in a continuous flow of gas and these have, in general only become available in commercial form since 1945. Instruments for the continuous quantitative analysis of carbon dioxide content have been in use much longer, but this measurement, although helpful to the control of a furnace, is not of such fundamental importance as that of oxygen. This is discussed in reference (*1*).

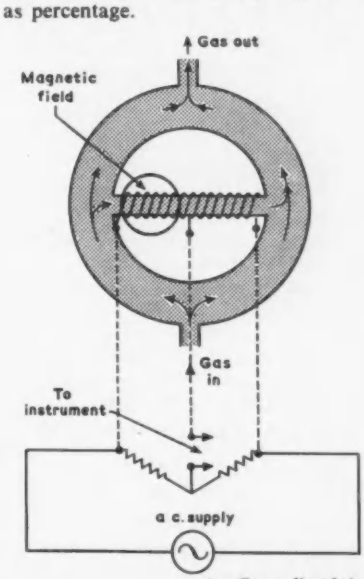
The reasons for the delay in the development of continuous-flow oxygen analysers can be seen in the practical difficulties of measuring the properties of oxygen. The most pronounced property is a remarkable ease of chemical combination with other elements or compounds, but this has not been greatly exploited in any British instrument for continuous flow usage, and resort has been made to more obscure parameters such as thermal conductivity and paramagnetism. Despite the practical problems, paramagnetism appears to be favoured, and considerable ingenuity and expertise have been brought to bear in the development of commercial analysers of this type. Nevertheless, a number of attempts in the last fifteen years to introduce oxygen analysers by firms in this country have quietly faded from view, and this only underlines the difficulties encountered in this field of development.

The instruments now to be briefly described have all been established in their current or similar form for some years, and the claim may be made that tried serviceable instruments are available for the analysis of oxygen content in continuously flowing gases.

Thermal conductivity

Fig. 1 illustrates the principle of the analyser of the Cambridge Instrument Co. Ltd., which relies on the thermal conductivity of oxygen differing from that of other gases. The measuring cells shown are four in number and each contains a platinum wire resistance with identical electrical and thermal characteristics enclosed in the solid metal katharometer block. Each wire is connected as a separate arm of a simple Wheatstone bridge in which, initially, constant bridge current is maintained with each cell open to the same gas. Each wire will eventually assume the same temperature and resistance.

If two of the cells are now disconnected from the common gas and a mixture of others with different thermal conductivity is substituted, the two cells will attain a new thermal equilibrium. This will unbalance the Wheatstone bridge so that a galvanometer connected across it would indicate the flow of an electric current. The magnitude of this current when the bridge is unbalanced can be calibrated in terms specific of the composition of the gaseous mixture expressed as percentage.



courtesy George Kent Ltd.

Fig. 2 The principle of an analyser depending upon the paramagnetic properties of oxygen

Whilst a qualitative description can be as brief as that just given, many approximations are necessary to achieve even a simple theory, and although this is of some help in increasing the understanding of the method it is not sound enough for quantitative use. In the practical case

the bridge output expressed as a voltage is usually proportional to small differences between the inverse conductivities of gases in the two pairs of cells, but this does not hold as the differences increase. The output voltage is also dependent upon the value of the bridge current raised to a power approaching three so that this current must be kept substantially constant, although it does not affect the instrument zero which is fixed by the properties of the reference gas.

Suitable precautions are taken in the manufacture and design of the instrument to protect mechanically and chemically the cell wires by a fine glass coating, and to obtain rapid response from each wire by making its dimensions and those of the surrounding cell volume small. The cells are in a massive metal block to give uniform thermal conditions to each and mechanical protection. The cell walls can be protected against corrosion.

This instrument can be used for differential measurements with the gas for comparison being passed through the pair of cells otherwise sealed with the reference gas. Its simplicity and robustness are attractive but it is not an absolute method of measuring oxygen content. In known conditions the very empiricism on which it depends can be of help as the scale can be arbitrarily marked to take account of side effects of the process under observation unrelated to the thermal conductivity of the gaseous mixture.

Paramagnetic instruments

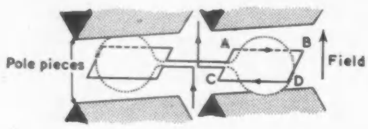
Instruments based on the paramagnetism of oxygen have been under active development in this country in two main forms (*2*): one physically of some elegance, and favoured by George Kent Ltd. and Cambridge Instrument Co. Ltd., which has no moving parts in the measuring elements; and the other depending on the deflexion of a torsion-suspended element in a non-uniform magnetic field established in the gas to be analysed.

Munday (*3*) and his team have worked in the Distillers Co. Ltd. for over ten years on an improved form of the suspended-element instrument, for which manufacturing and commercial rights have now been granted to Servomex Controls Ltd. Work cited in Munday's paper has also been undertaken abroad by Pauling and others in the U.S.A., and by Luft.

The Kent instrument is shown in Fig. 2. It consists of a tubular annulus with a diametral bridge and it is in the latter that the analysis is made. Gas flows through the instrument as shown by the arrows, and some is deflected into the tubular bridge by the intense magnetic field provided at one end of it, and acting in a direction along a diameter of the bridge. The diverted gas is heated by two adjacent identical platinum wire windings about the bridge, and the magnetic susceptibility of the ogygen content of the flow falls while fresh cool gas continues to enter the bridge and the warmed gas is forced towards the other arm of the annulus and so passes out of the bridge. The two platinum windings thus are caused to adopt different temperatures and the consequent disparity of electrical resistance upsets the balance of a Wheatstone net circuit of which the windings are adjacent elements. The potential difference which now appears across the detector of the bridge is measured by a self-balancing potentiometer of which the output is calibrated directly as percentage oxygen content of the gas being analysed.

Munday's instrument

Fig. 3 shows the measuring element of the instrument developed by Munday. The moving part is of fused silica of the shape of a dumb-bell. Havens (*4*) put forward this shape nearly



courtesy The Distillers Co. Ltd.

Fig. 3 Another analyser working on the paramagnetic principle

thirty years ago in his work on original measurements of the magnetic susceptibilities of gases. The dumb-bell is suspended in an intense non-uniform magnetic field by a filament which is put in torsion by the partial pressure of the oxygen content of the gas in the measuring cell in the magnetic field: the occurrence of the partial pressure under these conditions is the Quinke effect. Munday's improvement on earlier designs was to add the conducting coil shown in the figure wound about the dumb-bell and to provide a current in it of which the magnetic effect gave rise to a contrary torque to return the dumb-bell to the undisturbed position. In practice the current is obtained from a balanced d.c. amplifier and controlled in magnitude and sense by an input from a light source, optical system and pair of photocells which detect the position of rotation of the dumb-bell suspension. The instrument is consequently of null-balance type, and as the current feedback also damps the moving system it is of a much more robust construction than Havens and other workers were able to evolve. Changing the gain of the d.c. amplifier by a control switch permits several ranges of scale to be selected on the one instrument. The instrument is sensitive, has small error, and, whilst among the most expensive offered, has applications not open to some other designs (for example, in marine boiler operation, in conditions of vibration and in portable form), because it is comparatively unaffected by the precise level in which it rests while in use.

Chemical combination

Two instruments based on the chemical combination of oxygen with other elements serve specialized but important fields in metal furnace processes and vacuum products manufacture, and in the measurement of very low concentrations of oxygen for research and testing in nuclear energy applications. Both instruments are made by Engelhard Industries Ltd., that for the former purposes utilizing the measurement of the rise of temperature of the gas stream through the instrument resulting from the exothermic reaction of oxygen with hydrogen. The instrument for the determination of very low concentrations of oxygen uses a galvanic cell in which the gas through adsorption by one electrode goes into solution in the electrolyte as hydroxyl ions. The resulting electric current is proportional to the oxygen concentration in the sample gas with a linear relation for the lowest levels of concentration. Both instruments employ a self-contained electrolyser, in the first case to provide the hydrogen required for the reaction and in the second to produce an accurately measured quantity of oxygen for calibration by substitution.

Obtaining samples

No mention has so far been made of a major practical problem common to all gas stream analyser applications which is found in the methods of obtaining the sample of gas for analysis. A good treatment of this subject will be found in reference (*5*). The value of the best chosen instrument for oxygen analysis in any particular situation rests much upon the care given to obtaining the samples for it to measure.

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Manufacturer	Type of instrument	Ranges of % O_2	Error	Speed of response	Range of rate of flow of gas analysed	Output	Associated instruments	Approx. price and power supplies	Advantages and limitations
Cambridge Instrument Co. Ltd.	Based on the thermal conductivity of gas analysed compared to standard gas mixture in a katharometer. Can be used differentially.	0 — 0·3 or 0 — 0·5 in. N_2 differentially. 0 —3·0 in A 0 —5·0 in air.	Very small zero drift usually. Since the scale of the instrument is obtained empirically a quantitative value of error cannot be given. In an example it may be 4—5% of f.s.d.	In some examples it is of the order of 10 sec. as time constant, at a gas flow rate of 100 ml/min.	~50 ml/min to ≥450 ml/min.	Electrical; values set by nature of gases in which O_2 content is to be measured, the full scale deflexion obtained for the particular mixture is measured in millivolts.	Indicators, controllers, recorders. Also aspirators, filters, absorption chambers, flowmeters, gas condensation vapour removers. Two parallel outputs	£380 complete with accessories and indicator or recorder. ——— 6V accumulator or a.c. mains.	1. Can be made substantially independent of flow rate, and sample pressure and temperature. 2. Not initially dependent on horizontal level of installed instrument. 3. Affected by water vapour in the gas analysed and by nature of other gaseous mixtures.
	Based on paramagnetic properties of O_2, and the dependence of it on gas temp. giving rise to a 'magnetic wind'.	0 — 2 up to 0 — 100	Very small zero drift. ±1% of f.s.d. on all ranges.	6 sec. for 0—20% f.s.d.	Throttling valve controls value through instrument to 200 ml/min.	Electrical, e.g. 6mV corresponds to 0—20% f.s.d.	Substantially as above but with saturator instead of water vapour remover for flue gases.	£350 with additions as above. ——— 100VA at 200—250V, 50 c/s, single phase.	1. Analysis cell is in a thermostatically-controlled case and so independent of ambient temperatures. 2. Provision is made to reduce the inlet gas temperature to ambient, but it should not be >60°C. 3. Available with indicator in an intrinsically safe form. 4. Must be levelled for use.
Engelhard Industries Ltd.	'Deoxo' indicator utilizes rise in temperature from catalysed combination of the oxygen impurity with hydrogen generated electrolytically.	0·001—0·75.	±2% f.s.d.	Slow.	Controlled for all gas pressures up to 200 lb/in.²	Galvanometer indication proportional to % O_2; current supplied from thermopile subjected to the temperature rise.	Can be used with a recorder or controller.	£380.	1. Intended for small concentrations in the inert gases, H_2, N_2, CO_2, and saturated hydrocarbons. 2. Built-in calibrator. 3. Full scale deflexion adjustable over the full range. 4. Catalyst poisoned by some gases. Instrument unsuitable for others.
	Hersch oxygen meter uses a Ag-Cd galvanic cell with KOH as electrolyte; in this the O_2 is adsorbed by the Ag and then goes into solution as hydroxyl ions, the current in the external circuit being the measure of % O_2.	0—10 and 0—100 vols. per million.	±5% of f.s.d. if calibrated every eight hours.	Change indicated after 40s., and 90% f.s.d. achieved after 135s.	Regulated to 22½ l/h under inlet pressure of 2 lb/in.² boosted to this value if required.	Galvanometer indication of cell current. Linear scale for 0—10 rev/min but a calibration chart is needed for interpretation in the range 10—100 rev/min.	Booster pump for inlet gas if required. A recorder or controller can be connected to operate from the instrument.	£490.	1. Intended for very small concentrations met in research or special industrial conditions, e.g. in the nuclear energy field. 2. Built-in calibrator by substitution method. 3. Thermostat and saturator are incorporated, otherwise affected by gas ambient temperature and gas humidity.
George Kent Ltd.	Based on paramagnetism of O_2 and its dependence on gas temperature giving rise to a 'magnetic wind'.	0—2 up to 0—30 in 24 varieties of range over 1, 2, or 3 zones.	Very small zero drift. 0·05 or 1% f.s.d., whichever is greater.	Change indicated after 5s., and reaches 95% f.s.d. in 45s.	600—1,000 ml/min preferred but unaffected over the range 250—1,000 ml/min.	Electrical; measured in mV.	Operated in conjunction with Kent 'Multelec' potentiometer recorder and if required, with associated controller.	£380. ——— 100VA at 200—250V, 50 c/s, single phase.	1. Can be self-compensated for gas pressure changes (but pressure in the cell must be ≥1 lb/in²) and is self-compensating for ambient temperature. 2. Check point provided for connection to Orsat apparatus. 3. Must be levelled for use and protected from draughts and rapid temperature changes. 4. Inlet temperature from process gases must be <75°C or 49°C for rapid response. The flue gases must be at ≥454°C at sampling point.
Servomex Controls Ltd.	Type DCL-83 is based on paramagnetism of O_2 expressed in the Quincke effect to exert a force on a suspended Haven type dumb-bell.	0—1—100 in 6 ranges selected by switch.	0·1% f.s.d. or 1% f.s.d. whichever is the greater for the range, including zero drift over 7 days' operation.	90% of a step change in 10s. at a gas flow rate of 75 ml/min.	>0, <150 ml/min for gases of similar viscosity to that of air.	'Null-balance' electrical system incorporated gives 5mV d.c. for f.s.d.	Can be used to set a controller which is electrically-operated.	£800. ——— 250VA at 110—200—250V, 50 c/s, single phase.	1. 'Null-balance' feature gives freedom from supply change effects, damps the movement which can thus be more robust than in other Haven type designs. 2. Need not be precisely levelled. 3. Not affected by thermal conductivity variations. 4. Infrequent check calibration required.

Programme-controlled capstan lathe

Punched-card control gives greater efficiency

A SIMPLE FORM OF PRE-PROGRAMMED punched-card control is being used with some success on Alfred Herbert's No. 2D capstan lathe. This machine, which is one of the smaller Herbert capstan lathes, is capable of working on bar up to 1·5 in. in diameter or for chuck work up to 9 in. swing. There are eight reversible spindle speeds from 160-2550 rev/min, and a further eight reversible speeds are provided by pick-off gears.

Pre-punched programming

The programme control system used on the 2D lathe automatically selects spindle speeds and starts, reverses and stops the spindle, as required, when the turret is indexed. The system is claimed to reduce setting-up times, operational fatigue and also non-cutting times, but the fundamental advantage is said to be that the operator uses the correct speed for the particular operation. In effect, programme control not only eliminates the human element, but also ensures greater efficiency from unskilled labour, i.e better work and less tool-regrinding.

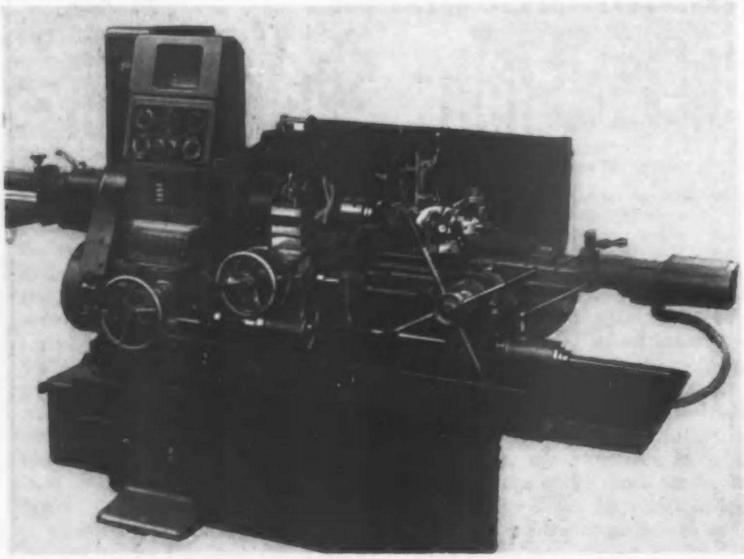


Fig. 1 Patch board control of this Herbert 2D capstan lathe regulates the speed, start, stop and reverse of the spindle as the turret is indexed

The system is based on the use of a punched board panel, rather like a patch panel (see Fig. 2), and limit switches. Shorting plugs inserted in the appropriate holes in the panel, select the required forward or reverse rotation of the spindle, spindle speed and spindle start and stop, and also a change of spindle rotation. The latter change might be required for withdrawal of a tap or for such operations from the rear toolpost as parting-off. Automatic selection is actuated by slots in a stop barrel, fitted to the end of the capstan slide, which operate limit switches (see Fig. 3). Thus, indexing of the turret at the end of the reverse traverse of the capstan slide, automatically selects the pre-programmed conditions for machining from the next turret face. Change of spindle direction, however, after a tapping operation, is automatically effected at the end of the forward stroke of the capstan slide.

Referring to Fig. 2, it will be seen that there are twelve vertical rows of holes in the punched plug board panel, a pair of holes to each of the turret's six faces. Under each turret face number on the panel, the top two horizontal rows of holes determine the direction of spindle rotation according to the positioning of the two-pin plug. A plug in row A, B, C or D determines which of the speeds of the four-speed pole-changing motor is required. A plug in either of the next two rows of holes will select 'fast' or 'slow' clutch, relative to each speed of the motors. Thus, any one of eight speeds can be selected for each turret face. A two-pin plug may also be inserted in the lower two rows of holes in the board, for either changing the direction of spindle rotation or for stopping the spindle. Fig. 2 shows

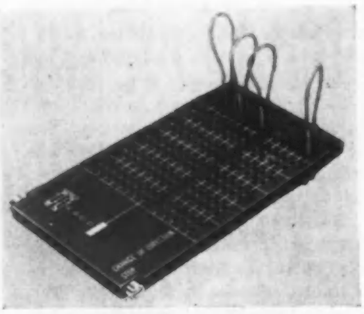
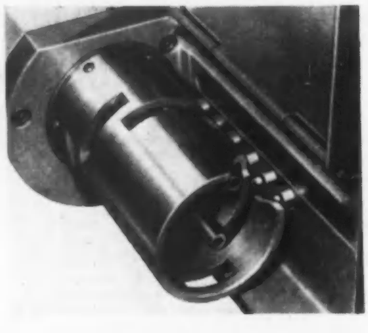


Fig. 2 Plugs are here inserted in the punched-board to control operations from face 6 only of the hexagon turret

Fig. 3 Slots in a stop barrel at the end of the capstan slide, operate limit switches to select the appropriate control circuits for each face of the turret



plugs inserted to control operations from face 6 only of the hexagon turret. It is in fact plugged-up to give clockwise rotation of the spindle, fast clutch, an intermediate speed of the motor and spindle stop.

Turret-controlled switching

Each of the turret's six faces has a limit switch associated with it, this switch being actuated when the turret is indexed at the end of a particular machining operation. Each turret-controlled limit switch will, when contacted, select the appropriate vertical double-row of holes on the plug board, so determining the direction of rotation of the spindle, the motor speed and, through magnetic clutches in a two-speed driving box, the spindle speed. The change in direction of spindle rotation, which will be required after a tapping operation, for example, is obtained at the end of the capstan slide's forward stroke by a stop bar and limit switch arrangement.

A pre-programmed punched card is normally superimposed over the plug board to ensure that the shorting plugs are inserted in the correct positions for a particular machining programme.

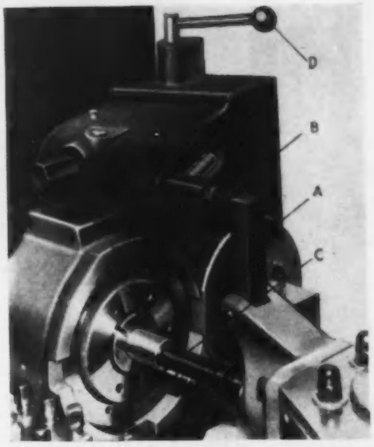


Fig. 4 The Herbert Autobar chuck gives automatic bar feeding to a pre-determined length. A, swivelling lever; B, servo bar; C, adjustable stop; D, lever for manual operation of the chuck

Automatic bar feeding

A further facility on the Herbert 2D capstan is automatic feeding of bar to the required length. This is provided by the 'Autobar' chuck illustrated in Fig. 4. Bars up to 8 ft long are fed to the 1·5 in. capacity chuck, which is a pneumatically operated 'dead-length' type. This Autobar automatic chuck opening and closing mechanism consists basically of an operating lever and an adjustable stop mounted on one face of the turret. Referring to Fig. 4, it can be seen that forward movement of the capstan slide will cause stop C to move lever A. The lever will swivel against bar B so opening a valve to admit air to a cylinder and thus open the chuck. Simultaneously, lever A pushes stop C forward. The bar, however, feeds forward against stop C, causing lever A to push servo bar B further into the headstock. This action opens an exhaust valve and the clutch closes. The chuck will, of course, remain open until the pre-set length of bar has been fed through it, this being determined by the setting of the turret slide and by the length of the adjustable stop. Lever D is used to operate the chuck by hand,

CONTROL IN ACTION

Breathing controlled automatically

AN 'ELECTRONIC LUNG' DEVELOPED AT the Barnet General Hospital and engineered by W. Watson & Sons Ltd. —a member of the Pye instrument group—is now in production by Watson (Patent Applications 4295/59 and 4296/59). Called the Barnet ventilator (because it 'ventilates' the lungs), it is understood to be the only device of its kind applicable to the alleviation of virtually all respiratory deficiency ailments. CONTROL understands that the equipment has been fully tested in the field, the original prototype having been used in Barnet General Hospital for seven years and subsequent prototype models used at Barnet and other hospitals.

Basically the equipment is a double-action pump which can either control a patient's inspiration and expiration, or assist the patient's respiration by reinforcing his own attempts to breathe. The Barnet ventilator can be set-up to handle most human respiratory conditions, although its advantages are probably best understood by comparing it with the iron lung.

CONTROL is informed that the iron lung is by no means a common item in the hospital's armoury, because—and despite publicity to the contrary—poliomyelitis is a rare disease in this country, and consequently the paralysis of the muscles of respiration which entails the use of an iron lung is rare.

The iron lung is essentially an air-tight box which completely encloses the patient, except for his head. Pumps vary the air pressure in the box between positive and negative values, each cycle causing the patient's lungs to inflate and deflate within the proper physiological limits.

The Barnet ventilator on the other hand, sustains breathing by literally pumping air into the lungs and, if necessary, pumping it out again. It can determine the number of respirations per minute, the ratio of inspiratory to expiratory time and the volume of air entering or (more usually) leaving the lungs. It weighs 56 lb only and, as can be seen in Fig. 1, is easily transportable and gives the patient a great deal of freedom. The patient in Fig. 1 appears to have undergone tracheostomy, the gas feed being directed into the windpipe. This is normal for long-period use, as in respiratory paralysis, but an endotracheal fitting would be employed or, more usually, a mouth fitting for the short periods necessary in treating bronchitis, or for anaesthesia.

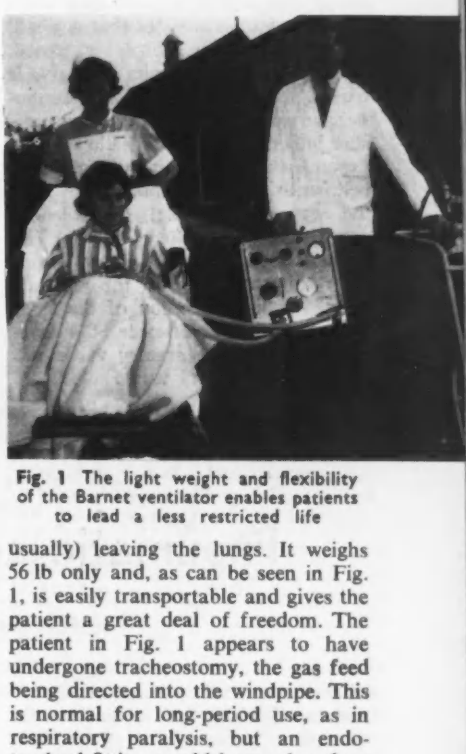


Fig. 1 The light weight and flexibility of the Barnet ventilator enables patients to lead a less restricted life

The general mode of operation of the ventilator will be apparent from Fig. 2. The inspiratory to expiratory ratio having been set at, say 1·25 sec to 4 sec, the solenoid will be opening and

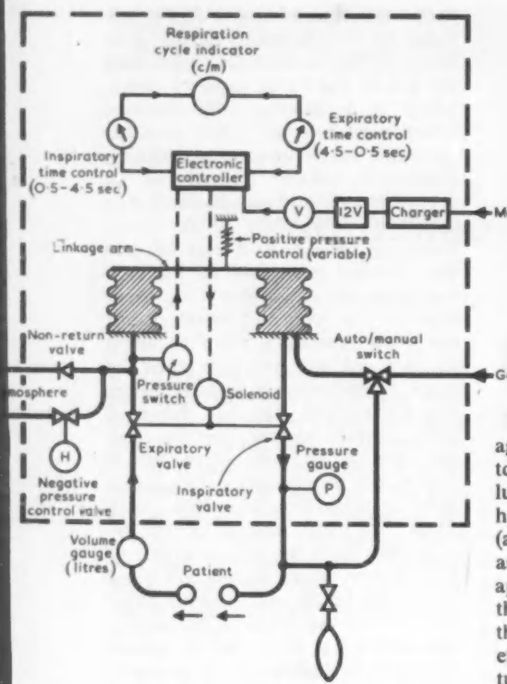


Fig. 2 The Barnet Ventilator is based on the use of two bellows whose operation is determined by time-controlled solenoid-operated valves

closing the inspiratory and expiratory valves in such a manner that one will be open while the other is closed. Assuming that the inspiratory valve is closed, gas—air, oxygen or anaesthetic, as required—will flow at low pressure into the inspiratory bellows. This expands (taking with it the expiratory bellows to which it is linked) and after the set period (4 sec), the solenoid opens the inspiratory valve. The spring-loaded bellows collapses, driving respiratory gas into the patient's lungs. At the conclusion of the (1·25 sec) inspiratory half-cycle, the solenoid closes the inspiratory valve and opens the expiratory valve.

The inspiratory bellows expands again, causing the expiratory bellows to expand and so exhaust the patient's lungs. Assuming that the patient's exhalation is controlled by the ventilator (and this is not necessarily so) as well as his inhalation, the negative pressure applied to his lungs is determined by the negative pressure control valve. As the diagram shows, the patient may exhale to atmosphere via a non-return valve. As the expiratory bellows expands, however, air will be forcibly exhausted from the lungs, the negative pressure involved being a function of the setting of the negative pressure valve.

The positive pressure is similarly controllable using the spring on the bellows linkage arm. Varying the tension of the spring will, of course, vary the rate at which the inspiratory bellows is collapsed, and hence the pressure that is applied to the lungs.

As the two bellows are linked mechanically, it follows that the positive pressure control will also determine the rate at which the expiratory bellows exhausts to atmosphere.

As described above, the rate of respiration is predetermined by the physician. The Barnet ventilator can, however, operate under the control of the patient. If the device is operating at some pre-set rate of respiration, and the patient inhales during the expiratory half-cycle, pressure will be sharply reduced at the expiratory bellows. A diaphragm-operated pressure switch will make, passing this information to the electronic controller. The latter will thenceforth control the solenoid, and its two associated bellows, in accordance with the patient's respiratory requirements.

The controls and indicators on the ventilator include the variable inspiratory and expiratory time controls, these being calibrated 0·5–4·5 sec. These controls operate a simple mechanical computer of the quadrant type, to provide a separate indication of respiratory cycle time. The positive and negative pressure controls are described above, and the pressure gauge is in the inspiratory line. The volume gauge measures in litres, and is external to the ventilator—normally in the expiratory line from the patient. Two mechanical indicators attached to the bellows linkage give visual indication that the ventilator is operating.

The only other indicator is a voltmeter which indicates the state of the battery supply. The machine is virtually independent of the mains. The bellows are gas powered, and the electronic time controller is transistorized and so requires little power. Connexion to a mains supply is usual in order that the 12-volt battery may be continuously trickle-charged. Should the mains fail, however, the ventilator will run for up to twenty hours without the need for battery recharging.

CONTROL IN ACTION

Pneumatic control of dispensers

Regentone employ rotary indexers for dispensing components

A 40% IMPROVEMENT IN EFFICIENCY IN their assembly section, is reported to have been achieved by Regentone Radio and Television after twenty 'Rotasembler' rotary storage and dispensing machines had been installed. The Rotasembler, which has been developed and is manufactured by Work Study Equipment, is a rotary indexing machine capable of storing large quantities of small components, and dispensing them in the correct sequence for assembly, to a point a few inches from the assembly area. The indexing mechanism is compressed-air-operated by pneumatic control equipment manufactured by Maxam Power Ltd. The machine eliminates the necessity for an operator to identify the various components of an assembly.

The twenty Rotasemblers at Regentone, store and dispense small electrical components, such as the resistors and capacitors used in producing printed-wiring radio and television receivers.

The Rotasembler is 28 in. in circumference and 26 in. high, and capable of storing up to 38 different components in 19 vertically-divided hoppers. It is claimed that the 38 hoppers, thus provided, can each store as many as 2000 small components. Fig. 1 shows an operator at Regentone taking a component from one of the 38

Fig. 1 Rotasembler in operation at Regentone's Romford works. The operator is fitting a component into a printed board, whilst simultaneously reaching for the next component

hoppers, while simultaneously inserting a second component into a printed wiring board. As can be seen, the feed lips of the two hoppers comprising each hopper unit are mounted one above the other, and fitted with adjustable gates to regulate the flow of components to each lip.

Although not apparent in Fig. 1, a separate Maxam foot valve and air cylinder arrangement folds over the wires or tags on the ends of each component inserted in the chassis.

Pneumatic indexing

The system of operation will be apparent from Fig. 2. The Rotasembler unit is carried on a Y-shaped mounting plate (B) which is bolted to the assembly area at three points. In the centre of the Y-plate is a rigid support shaft located on a mounting block reinforced by steel buttresses. Over this shaft is placed a hollow drive shaft with a bearing journal at the upper end, the indexing mechanism being attached to the lower end. Two sets of three spokes (I) radiate from the drive shaft and these are attached at their outer ends to two support rings (A) which carry the 19 removable double-hoppers.

The indexing mechanism comprises ratchet and fixed gear wheels (C) attached to the drive shaft. The ratchet gear is driven by a short chain attached to the centre of a pivoted lever (D) at one end and to a spring (H) at the other. The pivoted lever is moved by the piston of a Maxam trunnion-mounted 1·5-in. bore, 2-in. stroke double-acting air cylinder (E) which is normally in the extended position. When the Maxam foot-operated valve (K) is depressed by the assembly operator, compressed air passes to the forward end of the Maxam air cylinder causing the cylinder piston to retract which in turn moves the lever and chain. During this movement, the chain is drawn past the 'disengaged' ratchet gear, the spring taking up the slack.

When the foot valve is released, air passes to the mounting end of the cylinder, forcing the piston outward and thus moving the lever away from the ratchet gear. This draws the chain past the now 'engaged' gear so turning drive shaft and hoppers through some 19°.

A braking system mounted on one member of the Y-plate comes into operation simultaneously with the movement of the hoppers. The brake (G) is held 'on' by a cable (F) attached to the pivoted lever. When the lever is moved by the air cylinder on operation of the foot valve, the brake cable relaxes, releasing the brake. The brake shaft is driven by a chain looped around both a gear on that shaft and a fixed gear mounted above the ratchet gear on the drive shaft. As the cylinder piston extends on release of the foot valve, the lever moves outwards. This causes the chain to turn ratchet gear and drive shaft, and also the fixed gear which drives the brake shaft. This movement also tightens the brake cable and progressively brings the brake into operation.

Among the advantages claimed for the Rotasembler is the almost total elimination of assembly errors.

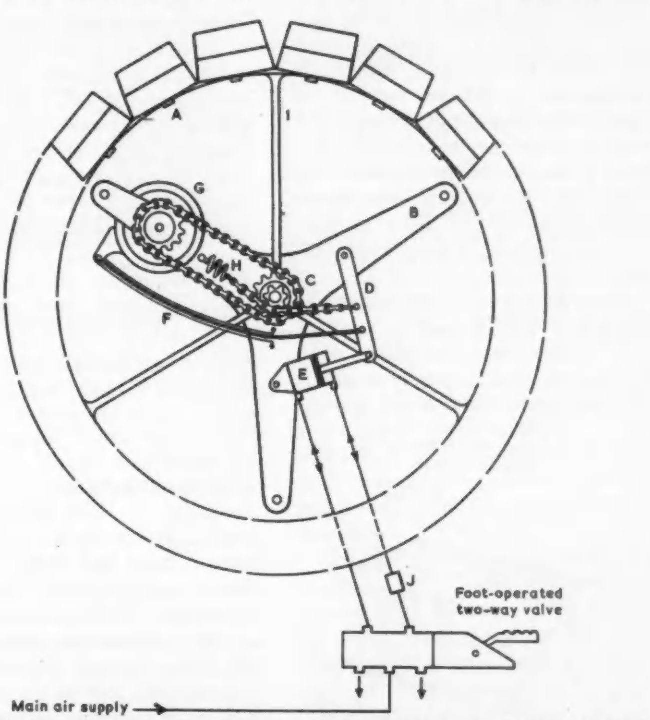


Fig. 2 The Rotasembler's pneumatically operated indexing system makes it possible to assemble up to 2000 components in an hour. A, ring of 38 hoppers; B Y-plate; C, ratchet and fixed gears on drive shaft; D, pivoted lever; E, Maxam air cylinder; F, brake cable; G, brake assembly; H, spring for chain slack; I, spokes attached to support ring; J, Maxam restrictor valve to slow outward/return movement of piston; K, Maxam foot-operated valve

A monthly review—under basic headings—of the latest control engineering developments for all industries; specially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

IDEAS APPLIED . . .

. . . to VELOCITY

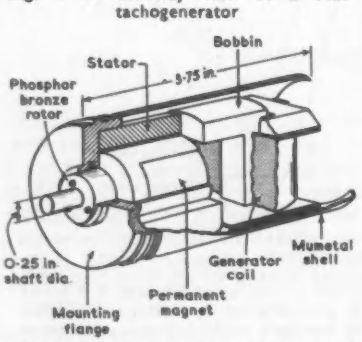
Small angle tachogenerator*

A. V. Roe Ltd., Weapons Division.
J. A. WADE

In conventional d.c. tachogenerators the armature conductors are rotated in a magnetic field which is contained in a radial air-gap formed between a cylindrical permanent magnet and a soft iron return path. The armature windings are usually bonded together to form a bell-like assembly which is entirely free of ferrous material. The absence of ferrous material in the armature is a necessary feature if the generated voltage is to be free of large transient voltage peaks occurring during commutation of each armature coil. Since the armature winding is unsupported by ferrous material, its rigidity is entirely dependent upon the bond provided by the varnish treatment given to the conductors, and under high acceleration and severe shock conditions this form of construction is prone to mechanical failure.

The limited angle tachogenerator is designed to operate over an angle of ±15°, since there are many servo applications where a d.c. generator is only required to work over a few degrees. Full use of this feature has been made in providing an extremely robust generator which has an output sensitivity far in excess of that obtained from conventional d.c. tachogenerators of the same frame size. The limited angle tachogenerator is suitable for use as a feedback generator where operation is required under high acceleration and shock conditions, and where a substantial driving torque is available. The construction of the 1 in. limited angle tachogenerator is shown in Fig. 1, the basic overall dimensions of which conform to the N.A.T.O. a.c. servomotor housing size 20, except in shaft size and overall length.

Fig. 1 A cut-away view of a 1 in. tachogenerator



*Published by courtesy of the Chief Engineer, Weapons Div., A. V. Roe Ltd.

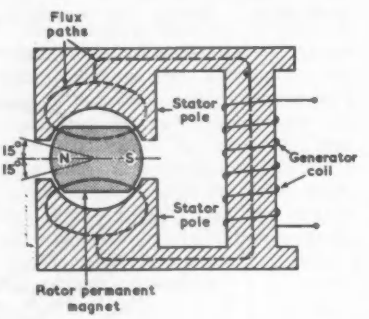


Fig. 2 Principle of generator operation

Operation

In the limited angle tachogenerator the generator rotor, which runs on large diameter sleeve bearings, contains a stable high-energy permanent magnet working into a soft iron stator containing two magnetic paths, one of which carries the generator winding. The principle of operation is shown in Fig. 2. With the rotor in the mid-position, that it with the magnet poles opposite the gaps between the stator poles, the magnet generates flux only in the stator poles. On turning the rotor away from the mid-position, the flux decreases in the stator poles and increases in the portion of the iron circuit which carries the generator winding. The stator and rotor pole shoe configuration is such that the output voltage is substantially proportional to the shaft speed over the limited rotor movement. A Mumetal shell provides screening of the generator winding from stray magnetic fields.

Sources of errors

1. *Frequency effect.* Since a large number of turns are contained in the stator winding, the generator impedance has a large reactive component. The choice of the gauge of wire and the number of turns used in the generator depends on the output required and on the degree of attenuation that is acceptable when the motion of the generator shaft is oscillatory.

The frequency of motion of the generator shaft at which the cut-off point occurs may be increased by using fewer turns in the generator winding at the expense of output. Similarly the cut-off frequency may be increased by connecting the generator to a high impedance load.

Under the oscillatory condition, eddy currents in the generator iron circuit produce a fall-off in output, particularly as the rotor moves from its centre position and the flux builds up in the main stator core. The stator core is therefore partially laminated to reduce eddy current losses.

2. *Temperature effects.* Changes in temperature affect the conductivity of the stator windings and the magnetic properties of the rotor magnet. Under the steady state condition, a change in conductivity of the stator winding of the order of 0·4%/°C produces a proportional variation in calibration of the generator. Under the oscillating condition the variation in output is

less since the reactive component of the impedance is predominant. The effect of temperature on the rotor magnet is only of the order of 0·02% variation in flux/°C, hence the change

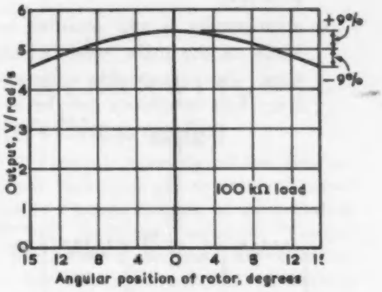


Fig. 3 The output of a 1 in. tachogenerator over 15° at constant rate

in winding conductivity is mainly responsible for the change in calibration of the generator with temperature. Temperature changes have no effect on the noise level at zero frequencies which is, in any case, extremely low due to the generator producing its own power.

The generator insulation is designed to operate under Class B conditions.

Performance

Two sizes of limited angle tachogenerator, having 1 in. and 3 in. diameter rotors respectively, have been manufactured by A. V. Roe & Co. Ltd.

The output volts/rotor angular position, for a steady rotor velocity, and the phase shift and output linearity characteristics for the 1 in. version, are shown in Figs. 3 and 4.

The sensitivity of 5 V/rad/s for the 1 in. version is equivalent to 500 V/1000 rev/min. Thus, for a discrimination of say 10 mV, a rotor speed of

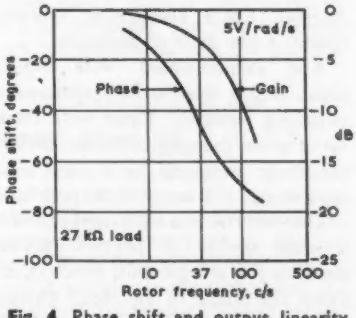


Fig. 4 Phase shift and output linearity for a 1 in. tachogenerator

0·02 rev/min may be measured. The sensitivity of the 3 in. version is 300 V/rad/s, so that for a discrimination of 10 mV a rotor speed of 7·1°/h may be measured.

Applications

There are many applications for the limited angle tachogenerator in control systems for both military and civilian use. The military use includes the velocity-feedback of control surfaces of aircraft, marine craft and missiles. The civilian applications include velocity-feedback of slow moving hydraulic rams and reciprocating slide beds of machine tools.

. . . to VIBRATION

A heavy damper

The damping of a heavy structure from severe shocks or vibration may often lengthen its life considerably. Electrohydraulics Ltd. have recently pointed out that the failure rate for protected structures is approximately 1/10 to 1/20 of those subject to unprotected conditions. An application in which this firm was concerned was the damping of severe shocks on the gas ducting of atomic power stations. These shocks may be imposed on the ducting in an earthquake, and it is essential that the ducts will not fail. A damper which they have designed to meet requirements like these is shown in Fig. 5. Moving axially within the cylinder is a piston which passes through a diaphragm, thus dividing the cylinder and forming a reservoir and damper chamber. Sealing rings are fitted between the diaphragm and the piston rod, and also between the gland and piston rod.

When the piston moves down the cylinder the fluid displaced passes through fluid connexion A, the restrictor, and subsequently into the reservoir. The fluid from the reservoir will at the same time be drawn unrestricted through connexion B into connexion C of the damper. Movement of the piston in the opposite direction reverses this flow sequence.

The one-way restrictors incorporaed in this unit limit the travel of the piston in the event of sudden movement; during a slower movement, they offer negligible resistance. Longitudinal drillings in the piston rod permit the passage of fluid through non-return valves to both the upper and lower faces of the piston during recharging of the unit. During this process fluid is discharged via the reservoir and out at a fluid level connexion. Recharging does not interfere with the damper function, and if the structure flexes while recharging is in pro-

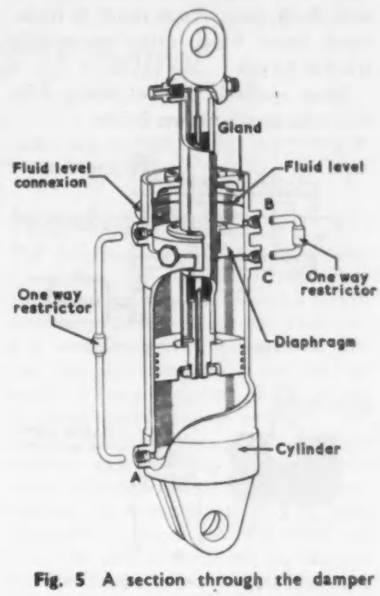


Fig. 5 A section through the damper

cess, high pressure from the damper is prevented from reaching the filling lines by the non-return valves.

. . . to SERVOS

An introduction to hydraulic servo valves—3

R. HADEKEL, Engineering Consultant, Sperry Gyroscope Co. Ltd.

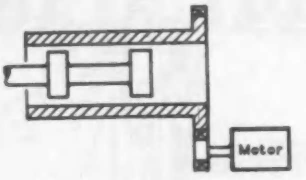
This series of articles is addressed to engineers who are conversant with servo techniques in general, and who wish to acquire specialized information on hydraulic servo techniques. The first part dealt with one of the keys to these techniques—the servo valve. The second part gave the basic types of valves and their characteristics. Here the loads on slide valves and the types of two-stage valves are discussed.

Owing to the limited force and stiffness available from the driving device, especially if this is a torque motor, a good understanding of the loads on valves is essential for successful valve design.

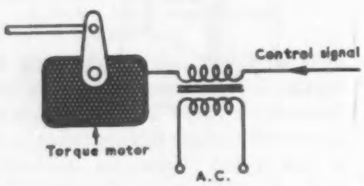
Circular cylindrical slide valves are nominally balanced as regards forces transverse to the axis, but in practice this is far from being the case. One reason is that departures from the ideal cylindrical shape owing to manufacturing imperfections are comparable in magnitude to valve clearances, and this results in distortion of the theoretically symmetrical pressure distribution pattern around the lands.

The other reason is that minute particles of dirt lodge at the edge of the lands and cast low pressure shadows, again distorting the pressure distribution. Both these effects result in transverse forces which cause appreciable friction forces.

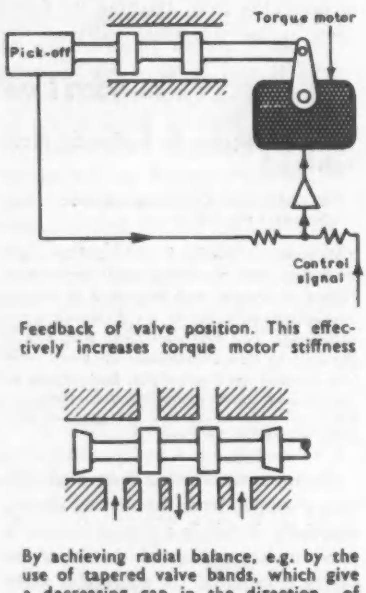
Some methods of overcoming friction effects are shown below.



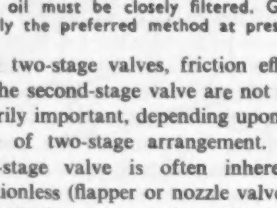
A rotation of the valve sleeve



A dither applied to the input. Its frequency must be high enough to avoid unpleasant effects in system



Feedback of valve position. This effectively increases torque motor stiffness



By achieving radial balance, e.g. by the use of tapered valve bands, which give a decreasing gap in the direction of flow. Very fine tapers (comparable with the valve clearances) are required, and the oil must be closely filtered. Generally the preferred method at present

In two-stage valves, friction effects on the second-stage valve are not necessarily important, depending upon the type of two-stage arrangement. The first-stage valve is often inherently frictionless (flapper or nozzle valve).

Hydrodynamic or Bernoulli forces arise from axial components of the momentum of the fluid in the orifice jets, and are proportional to $q\sqrt{(\delta p)}$, where q is the flow and δp the pressure drop in the orifice concerned. They always tend to centre the valve. These forces are important as

1. they may determine the size of the torque motor;
2. they may have destabilizing action, as they tend to reduce the slope of the pressure-flow curves (and in extreme cases might result in a negative slope).

Methods of compensating Bernoulli forces have been devised (particularly at the M.I.T.), but have not become popular as they are constructionally difficult, and it is usually considered easier (in those cases where the forces might be troublesome) to overcome the difficulty by using two-stage valve arrangements.

Two-stage valves

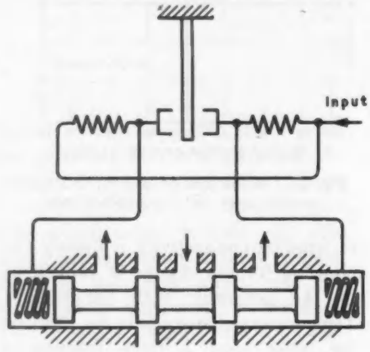
Probably the vast majority of electrohydraulic servo valves available and in use are of the two-stage type. As implied in the foregoing text, two-stage arrangements are used essentially to reduce the work required (from the torque motor) to operate the valve, either because it would otherwise be inconveniently high or because the nature and magnitude of the forces involved on the main valve (particularly friction) would otherwise result in undesirable characteristics. Basic arrangements are equally applicable to all types of valves, both as regards first and second stages. The second stage is almost always a cylindrical slide valve; the first stage may also be a slide valve, or a flapper valve, or a nozzle valve.

Differential pressure is usually generated by a flapper valve (which in the static condition produces a pressure differential proportional to valve displacement, or torque motor load); a first-stage slide valve is equally usable in theory.

An open-loop two-stage arrangement

As shown in the diagram below the second-stage valve itself forms the piston. Main features are:

1. simplicity and low cost;
2. gain is highly sensitive to supply pressure;
3. arrangement is still sensitive to loads on the main valve, which must be reasonably friction free. This sensitivity can be reduced by using a high spring rate, but only at the cost of increased standing losses from the first stage.



A two-stage valve

to be concluded

. . to REVOLUTIONS and RECOGNITION

A recent demonstration by Mullard showed some of the uses of Combi Elements, one of their range of 'building bricks'.

A number of elements were combined into a unit which counted the number of revolutions made by a shaft, and indicated direction of rotation by comparing the phase of signals from two pick-ups at right angles. Depending upon phase, the count is routed through an 'add' or 'subtract' channel, hence eliminating spurious results if the shaft is oscillating.

Also demonstrated were Norbit units, which are basically transistor switching elements. These were made up to show the application of transistor static switching to a variety of sequencing and recognition problems.

The basis of one such application is a small matrix of photo-transistors connected to a logic unit, which determines the shape of an object passing the matrix unit. The sequence of objects may be predetermined in the logic unit, and it may be arranged that an alarm signal is given if the sequence is disturbed.

NEWS ROUND-UP

from the world of control

—INTERNATIONAL—

Ifac's Chicago meeting

The General Assembly of the International Federation of Automatic Control met in Chicago recently, at the invitation of the American Automatic Control Council. With President H. Chestnut in the chair, the delegates of thirteen national member organizations, having been authorized to represent five additional member organizations, resolved on a new Constitution, elected members to the Executive Council, and discussed the first Ifac Congress which is to be held in Moscow from June 27 to July 6, 1960.

The Executive Council now consists of A. M. Letov (U.S.S.R.), President; H. Chestnut (U.S.A.), Past President; Ed Gerecke (Switzerland), First Vice President; O. Benedikt (Hungary), Second Vice President; M. Cuénod (Switzerland), Treasurer; J. G. Balchen (Norway); J. F. Coales (U.K.); G. Evangelisti (Italy); K. Kaneshige (Japan); P. J. Nowacki (Poland); and Z. Trnka (Czechoslovakia). D. P. Eckman (U.S.A.) remains Chairman of the Advisory Committee and J. Loeb (France) was appointed Vice-Chairman. V. Broide (French citizen) was reappointed as Honorary Editor, and G. Ruppel (Germany) as Honorary Secretary.

About 420 abstracts from 19 countries were submitted for presentation at the forthcoming Moscow Congress, and about 300 authors were invited to submit their papers. Both papers and discussions will be presented for the most part in English or Russian, but it is thought that translations from and into French and German will be possible also.

The British member organization of Ifac is, of course, the British Conference on Automation and Computation.

—BUSINESS—

Famous names go

The recent announcement by Lord Chandos, Chairman of the A.E.I. companies, that British Thomson-Houston, Metropolitan-Vickers Electrical and Siemens Edison Swan are no more, came as a shock to many in the British electrical industry. These famous concerns become Associated Electrical Industries (Rugby) Ltd., Associated Electrical Industries (Manchester) Ltd., and Associated Electrical Industries (Woolwich) Ltd., respectively. This is, of course, part of the reorganization of the A.E.I. group, a process which has been under way for several years and is now nearing completion.

The reasons given for these changes of name are connected with avoiding duplication and overlap between the various A.E.I. firms, the possibility of confusion in customer's minds as to which company provides which product, and the necessity for a general tidying-up process in order that the group may trade as A.E.I.

Although it must be assumed that A.E.I. knows its own business best, one would have thought that—sentiment apart—names like Metropolitan-Vickers, B.T.H. and Siemens Edison Swan had a commercial value for outweighing any advantage accruing from rationalization. However, on January 1, 1960, they will no longer exist as trading organizations, although their names may continue to some extent in the form of trade marks.

The A.E.I. organization

Manchester The three companies will, under their new names, manage A.E.I.'s twelve Product Divisions. Thus Associated Electrical Industries (Manchester) Ltd.—ex-Metro-Vick.—will control the Turbine Generator, Switchgear, Transformer, Traction and Instrumentation Divisions. The latter Division combines the interests of Sunvic Controls Ltd. (which also goes) with the Instrument and Meter, X-ray, and Scientific Apparatus departments of M.-V.

Rugby Associated Electrical Industries (Rugby) Ltd.—ex-B.T.H.—is to manage the Heavy Plant, Motor and Control Gear, and Electronic Apparatus Divisions, together with A.E.I.-Birlec Ltd. (the new name for the Birlec heat treatment and furnace manufacturing company), and A.E.I. Lamp and Lighting Co. Ltd.

Woolwich The interets of the Siemens Edison Swan Cables Division are combined with those of W. T. Henley's Telegraph Works Co. and Liverpool Electric Cables Ltd., in the new A.E.I. Cable and Construction Divisions which are to be managed by Associated Electrical Industries (Woolwich) Ltd. The other Divisions within the Woolwich (ex-Siemens Edison Swan) group include Telecommunications, and Radio and Electronic Components.

A.E.I., the largest British electrical manufacturer, although a relatively new name, is now more than ever a power to be reckoned with.

Pacemaking in Sussex

The American concern Electronic Associates Inc., manufacturer of the Pace analogue computer, has formed a British subsidiary company Electronic Associates Ltd., at Victoria Road, Burgess Hill, Sussex. The new company is equipped to study all types of system, to design and construct special-purpose analogue computers and simulators based on Pace modules, and to supply their other products. In addition it will train Pace operation and maintenance personnel for users, and provide before and after sales service. The British works will be managed by H. Turner, a director of Electronic Associates Inc., and the Managing Director is B. Murphy, who is General Manager of E.A. Inc.'s European (Brussels) branch.

JASON CHASTENED. Sir John Cockcroft starts-up Jason, the Hawker Siddeley Nuclear Power Co.'s first reactor, at Langley, Bucks. EMI closed-circuit television relayed the scene to remote monitors

—ATOMIC ENERGY—

A busy month

Merlin

November was a busy period in the world of nuclear power. On the 6th, A.E.I.'s own private research reactor, Merlin, was officially opened at Aldermaston by the Duke of Edinburgh. CONTROL understands that some difficulty was experienced in starting up Merlin owing to a 'control failure'. It appears, however, that an electrical fault had caused a control rod to drop in before

H.R.H.'s attempt to start-up the reactor. The control system had in fact failed safely.

Fast breeder at Dounreay critical

Information on the control characteristics and physics of fast breeder reactors will start to become available following the going-critical of the U.K.A.E.A.'s experimental reactor at Dounreay on the 14th. This is a plutonium producer which employs a liquid metal (sodium potassium) as coolant and for steam raising. The metal is circulated by electromagnetic pumps.

Neutron project

A.E.R.E. Harwell's neutron-project laboratory became operational on the 5th. This extends over twenty acres and houses what may well be the world's most extensive range of neutron time-of-flight spectrometers.

The laboratory is centred on a machine which might be described as a combined electron linear accelerator and sub-critical fast reactor. The accelerator generates an intense pulsed beam of electrons which impinges upon a mercury target to produce X-rays. These are directed upon a uranium target to produce neutrons. In effect, the uranium target acts as a sub-critical fast reactor. Without electrons it will shut down and generate no neutrons. During the pulse, however, the neutrons produced from the electrons stimulate the reactor to burn at 10 MW and so release many more neutrons than could have been produced by the electron beam alone. The reactor is quiescent in between pulses and the mean nuclear output is, therefore, about 2½ kilowatts only.

The accelerator is a travelling-wave linear electron type by Metro-Vick—now Associated Electrical Industries (Manchester)—which produces an instantaneous beam current of ¼ amp at 30 MeV.

Neutron time-of-flight measurement

An electronic timing technique determines neutron velocity. Neutrons from a pulsed source are allowed to travel down a number of 650-ft long evacuated 'flight-tubes' which radiate out from the source like the spokes of a wheel. Speeds are determined by measuring the time between the start of a pulse and the arrival of neutrons at the end of the tube. The present machine can liberate some 10^{11} neutrons in $0{\cdot}25\,\mu s$. The laboratory is interested in neutron speeds between 500 and 5,000,000 m/s.

Already twelve experiments have been laid out in the area surrounding the heavily shielded building. Plans are now under way for a 980-ft long flight tube.

Windscale

The advanced gas-cooled reactor at Windscale is to have burst slug detection by Plessey Nucleonics. The system is based upon a square matrix arrangement of the fuel sampling pipes in that 16 'x' co-ordinate detectors and 16 'y' co-ordinate detectors are employed to give continuous monitoring of the 253 fuel channels, without sequential gas sampling. Eight detector units are housed in one pressure vessel, so that a total of four such assemblies is required for the complete installation. Output signals from each detector are processed by transistorized ratemeters, using printed circuits, and the data are displayed in the control room by means of four eight-point recorders of conventional design.

Incidentally, it was announced on the 16th that the United States Atomic Energy Commission and the U.K.A.E.A. have signed a five-year agreement to exchange technical information on advanced gas-cooled reactors.

From Argonaut to Nestor

The U.K.A.E.A. are purchasing a Nestor (neutron source thermal) reactor from Hawker Siddeley Nuclear Power Co. This is based upon the latter's Jason reactor which itself grew out of the Argonne National Laboratory's Argonaut.

The first operational Jason was officially inaugurated by Sir John Cockcroft at Hawker Siddeley's Langley, Bucks., works on the 24th. A reactor simulator at Langley carried an amusing quotation by Warren Weaver of N.R.D.C.: 'The control art is an old one. With the broadest definition, it is a very ancient art; for one supposes that if Adam wished to control Eve's vocal output, he had a simple mechanism, such as a well-balanced club, with which he doubtless brought it down a goodly number of decibels'.

B.E.A.'s COMET TAKE OFF. A training flight-simulator for the de Havilland Comet IVB jet aircraft was handed over by the Air Trainers Link division of General Precision Systems to British European Airways in November. Top: interior of the simulator's cockpit; bottom: instructors' control position. Incidentally, Air Trainers have delivered a prototype flight simulator for the English Electric Lightning fighter aircraft to an East Anglian R.A.F. station

—COMPONENTS—

High yields at Hazel Grove

Some 70,000 transistors and diodes are produced every week at G.E.C. Semiconductor Division's Hazel Grove fac-

tory, which CONTROL visited recently. An average yield of between 70% and 80% is claimed by the company, 'with the yield on one device as high as 90%'. Over 100 types of semiconductor are produced at Hazel Grove including low-power a.f., r.f., and power transistors; low-power silicon junction diodes; and medium-power silicon junction, diffused junction silicon, and germanium junction rectifiers.

CONTROL was at Hazel Grove during the recent water shortage in that area. As the local reservoirs were extremely low at the time—they contained but four days' supply—a certain amount of organic material was finding its way into the mains. A great deal of high-purity water is employed in the manufacture of semiconductors and de-ionized mains water is normally satisfactory. However, de-ionization will not remove organic matter and so trouble was being experienced. Some water was being brought in from elsewhere by tanker, and it is understood that plans have been made for sinking a bore hole.

The days of fanatical cleanliness in transistor manufacture seem to be passing. Hazel Grove, although reasonably aseptic, does not go in for that clinical cleanliness which used to be considered vital if a low reject rate was to be obtained. Apparently experience has shown many of the more dramatic precautions to be quite unnecessary.

Glass-to-metal sealing

Among the more interesting processes was a G.E.C. technique for producing good glass-to-metal seals. The components are assembled, jigged and placed radially in a centrifuge consisting of a rotating annular boat with a lid, which is enclosed in a firebrick enclosure. The boat is flushed with an inert gas and heated by gas jets. The required speed of rotation having been set up, the cycle begins. The brick lid automatically descends to enclose the rotating boat and triggers the gas-air supply to heat boat and contents to a pre-set temperature. The temperature is held at this level for a given period, after which the gas is turned off and forced-air cooling under controlled conditions anneals the seals.

Cold welding

Cold welding is used for the hermetic sealing of semiconductors at Hazel Grove, a homogeneous weld being obtained without the application of heat. The surfaces of the metals to be joined are thoroughly cleaned and the metals compressed between dies. The surface films remaining after cleaning are dispersed by the lateral flow of the mating surfaces, so that contact under pressure is obtained between perfectly clean metals. In such a weld the metal is continuous across the join.

Crystal thickness measurement

An automatic crystal measuring machine developed by G.E.C. is used to sort 1200 germanium or silicon wafers an hour, channelling them for different furnace temperatures according to thickness. The device is based on Southern Instruments' 'Magna-Gauge'. Each wafer is contacted by a capacitance probe and the resulting signal is fed to the comparator gauge before being transferred to a 'memory' box. The signal operates a solenoid-controlled chute to place each wafer in a particular size range. The same signal operates a counting device so that wafers may be sorted in batches of 200.

1200 germanium or silicon wafers an hour are sorted for thickness by this machine at G.E.C., Hazel Grove

DATA PROCESSING

Electronic digitizing

The Brit.I.R.E.'s Symposium on Electtronic Digitizing Techniques, which was held on November 18, was well attended, the younger engineers in particular showing great interest. The Symposium opened with 'A Survey of Digitizing Techniques' by G. J. Herring of R.A.E.'s g.w. department. He discussed applications and the two main groups into which converters fall: mechanical and electronic, the former being slower but more accurate than the latter.

'A Simple Analogue-to-Digital Converter with Non-Linearity Compensation' by W. N. Jenkins of Bisra, described a high-speed electromechanical switch (a motor driven uniselector) with a transistor switching amplifier. This can be used to digitize from most types of potentiometer recorder.

G. P. Tonkin of Bristol Aircraft described a digital potentiometer, for measurements in multiple installations of strain gauges etc., in his paper 'The Step-by-Step Potentiometer as a Digitizer'. In this instrument, resistances are successively paralleled by relays to modify the current in a standard resistor, and hence the potential difference, until balance occurs.

'An Analogue-Digital Converter with Long Life' by R. L. Gilbert of Marconi Instruments, described an instrument for converting small voltages representing a measured parameter into a digital representation. The device has a high input impedance, long service-free life, an accuracy of 0·1% of full-scale deflexion and a conversion time of 25 ms or less.

J. A. Irvine and D. A. Pucknell of Ferranti, Edinburgh, described 'A Wide Range Fully Automatic Digital Voltmeter' and demonstrated a high-impedance, three-digit voltmeter with automatic polarity and range selection and an accuracy of ± 1 digit over the range 10 mV–1000 V.

'An All Electronic Four Digit Voltmeter' by H. Fuchs and D. Wheable of Blackburn Electronics, dealt with the operation of the device and problems solved in engineering it. The automatic range-change circuit, which operates the input attenuator and deals with the errors arising from reverse grid current flowing in this attenuator, was described.

The discussion which followed brought out the considerable interest which exists in the digital presentation of data. The demand for digital presentation is growing rapidly. A representative of the motor car industry, for example, said that he employed a great deal of digital indication, albeit somewhat crude and simple, in order to obtain a record in a bouncing vehicle.

An amusing series of questions led to a trial of strength between the Ferranti and Blackburn Electronics' digital volt-

meters. Most people were relieved when both instruments gave much the same answer.

Orion fast and powerful

The prototype model of Orion, Ferranti's high-speed data processing system, is nearly complete and production has begun. The system is fully transistorized and incorporates Neuron logical elements enabling complex systems to be built around the central computer with the minimum of components. Facilities are provided for automatically sharing the time of the central computer between several programmes. Other notable features of Orion are automatic safeguards, known as lock-outs and lock-ins, which ensure that programmes in the computer cannot interfere with each other.

The computer has a magnetic-core working store of capacity between 1024 and 16,384 words, this being backed by magnetic drum units which are treated as peripheral devices. Addition and subtraction will take 36–68 μs, multiplication 60–200 μs, and division 300–900 μs.

Magnetic tape will be processed at high speeds. For example, 4½ million words can be read or written by the computer in one minute. Various high-speed printers may be attached, including the Xeronic which can produce up to 3000 lines of finished data per minute.

Although smaller than Perseus, Orion will be up to twenty times faster and three to four times as fast as Mercury.

CONTROL understands that the price of the system will fall within the range £100,000 to £300,000.

—ELECTRONICS—

Particles and furniture

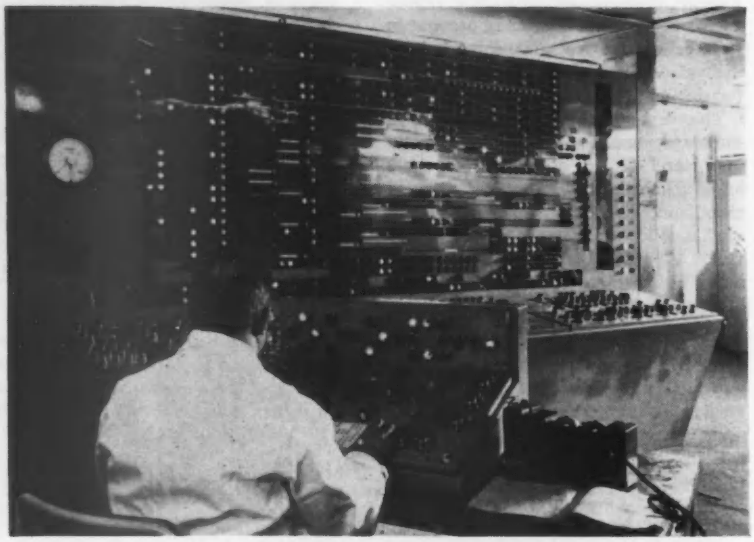
Lord Adrian was guest of honour at the recent joint annual dinner of the Radio Industry Council and the Electronic Engineering Association. He was introduced to the electronics industry by Lord Brabazon who said that, while he admired the specialist who knew all about the shape of a particular kind of mosquito's wings in a part of Africa, he did not know why he should consider this fellow's opinion on anything else. A man like Lord Adrian, however, who knew 'a lot about a *lot* of science', was a very valuable man.

Lord Adrian, who is Master of Trinity, Cambridge, proposed the toast to the industry. Electrons had been familiar enough in the days of J. J. Thomson and Rutherford, he said, but now we had an electronics industry exporting yearly goods worth £60 million. Its products were used for the control of engineering plant, and probably also for the control of the engineers themselves. Electronics people had not indulged in Latinate nomenclature like the medical fraternity, but had added attractive new words like 'wobbulator' to the English language. The practical achievements of his hosts, concluded Lord Adrian, showed atoms and electrons to be at least as real as tables and chairs, though this inference might seem hasty to the Oxford school of linguistic philosophers.

—MOTOR CARS—

Ford's nine miles of conveyer

The Ford Motor Co.'s new paint, trim and assembly plant, which CONTROL visited recently, is a £10 million two-storey structure, measuring 1215 ft by 630 ft, which is connected to the body shop by a 725-ft long bridge. The conveyer system used for the movement of motor car bodies through the plant is by Geo. W. King of Stevenage, and is some nine or more miles in total length and capable of holding over 1000 bodies in various stages of paint and trim.



One of the control rooms for the motor-car body conveyers of the Ford Motor Co.'s new paint, trim and assembly plant at Dagenham

. . . automatically controlled ?

The conveyer installation is described as being entirely automatic. It comprises overhead and floor conveyers incorporating a system of indexers which call bodies from one section to another, with automatic transfer sections for movement from one system to another. This includes passing the painted bodies from the paint shop on the first floor to the trim and assembly shop below. There are two main control rooms in the new plant. One on the first floor (illustrated), tracks and controls the flow of bodies through the entire paint system. A similar control room on the ground floor controls all conveyers and transfer equipment in the assembly system. Supplementary control panels are sited around the plant where required, e.g., for the diversion of bodies on to repair conveyers.

The form of control employed is somewhat negative, in that the two main control panels are, strictly, mimic diagrams which indicate the flow of bodies and call attention to any hold-up. Such control as is carried out is under manual, rather than automatic, supervision. The reasons for the absence of closed-loop controls are, of course, bound up with Ford's need for flexibility in the flow-line production of motor-car bodies of varying type and colour scheme.

—AIRCRAFT—

Hydraulics for the V.C.10

Vickers hydraulic units by Vickers Inc. of Detroit are manufactured in this country by Sperry Gyroscope, and the latter have received an order from Vickers-Armstrongs Aircraft (no connexion with Vickers Inc.) for such equipment for the new V.C.10 long-range jet airliners. Four Vickers hydraulic pumps—one to each of the V.C.10's four Rolls-Royce Conway engines—are to provide power for the aircraft's main hydraulic services, comprising powered flying controls, undercarriage raising and lowering, nose wheel steering, brakes etc.

Six Vickers hydraulic motors will also be fitted to each aircraft, four for operation of the leading-edge slats and flaps, and the other two to control tailplane incidence.

—NEWS BRIEFS—

'Training Regulations', now available from the Secretary, The Institution of Electrical Engineers, Savoy Place, London, W.C.2, outlines the I.E.E.'s require-

ments for the education and training of a professional engineer.

'Pulse', published by Kelvin & Hughes (Industrial) provides information on non-destructive testing and electronic instrumentation.

'Russian Patents Gazette' abstracts Russian patents (Opisanie Izobretenii) and is published by Technical Information Co., Chancery House, Chancery Lane, London, W.C.2.

Printed circuits: a series of six lectures on this subject will be given by P. G. L. Vivian of Ultra Electric at Norwood Technical College (Knight's Hill, West Norwood, London, S.E.27) on Tuesday evenings beginning January 12, 1960.

AMP Inc., U.S.A. (solderless terminals, connectors and crimping tools) now has four European subsidiaries: AMP Italia S.p.A., Turin; Deutsche AMP G.m.b.H., Düsseldorf; Société AMP de France; AMP Holland N.V.; Aircraft Marine Products (G.B.) Ltd. The latter have moved to 87–89 Saffron Hill, London, E.C.1; Telephone: Chancery 2902–8.

Modac connectors by Plessey associate Modern Acoustics Ltd. are now manufactured by Plessey's Wiring and Connectors Division at Cheney Manor, Swindon. This Division now produces all electrical connectors.

Laurence, Scott & Electromotors wish to contact ex-apprentices of the firm for a possible re-union. Contacts: W. F. Symes at Gothic Works, Norwich, or telephone T. J. Barfield in London, TEM 5223.

I.C.T. Australia: the Hollerith and Powers-Samas interests in Australia have been taken over by International Computers and Tabulators Australia Pty. Ltd. under Chairman Sir Alexander Fitzgerald, Deputy Chairman C. W. R. Boyce and Directors F. G. Dowding, W. H. Jones, E. C. Howie and G. A. Redhouse.

Radio Research Station, Slough: J. A. Ratcliffe will be Director from October 1, 1960, when R. L. Smith-Rose retires.

Industrial Training Council concerned with 'the problem of finding sufficient trained men, scientists, craftsmen and management' has been set up by the Central London Productivity Association.

Lang Pneumatic have installed Telex in London (23128) and Wolverhampton (33193). A branch has been opened at 107 Pinstone Street, Sheffield, 1 (Telephone: Sheffield 27865) under Representatives J. M. Kenworthy and G. Shaw.

Level controls type TLC, transistorized capacitance-operated, by Lancashire Dynamo Electronic Products, are approved as intrinsically safe for hydrogen/ethylene/pentane class gases.

Datum Metal Products Ltd. have moved into a new factory at Colne Way Trading Estate, The By-Pass, Watford, Herts. (Telephone: Watford 22351).

Bristol-Ferranti Bloodhound, semi-active homing surface-to-air weapon, which is in service with the R.A.F. and in Sweden, has been ordered by the Australian Ministry of Defence.

Closed-circuit television division covering the Marconi Co.'s activities in the military, scientific, industrial, commercial and educational applications of closed-circuit TV, has been set up under V. J. Cooper (Manager and Chief Engineer), J. E. H. Brace (Deputy Manager and Chief of Sales and Contracts), and N. N. Parker-Smith (Chief Development Engineer).

Pegasus digital computers have been ordered from Ferranti by the Road Research Laboratory of D.S.I.R. and by the Operational Research Department of the Steel Co. of Wales.

Gresham Automation Ltd. has been formed to handle the Gresham unit sequencing system. Directors are J. P. Coleman (Chairman of Gresham Transformers and the Gresham Lion group) and R. M. Campbell (Director of Gresham Transformers). Dr. D. B. Foster is consultant to the Board.

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.S. British Computer Society, Brit. I.R.E. British Institution of Radio Engineers, I.E.E. Institution of Electrical Engineers, R.Ae.S. Royal Aeronautical Society, S.I.T. Society of Instrument Technology.

TUESDAY 15 DECEMBER
Discussion on *Data Handling Problems in Atomic Installations* (Opened by D. Taylor). I.E.E.

TUESDAY 15 DECEMBER
Half-day Symposium on *Magnetic Recording Techniques*. 3 p.m. and 6 p.m. Brit.I.R.E.

WEDNESDAY 16 DECEMBER
Random Inputs and Load Variations by J. F. Coales. 6.30 for 7.0 p.m. S.I.T.

WEDNESDAY 30—THURSDAY 31 DECEMBER
I.E.E. Christmas Holiday Lecture *Colour Television* by G. G. Gouriet 3 p.m.

TUESDAY 5—THURSDAY 7 JANUARY 1960
Symposium on *Recent Mechanical Engineering Developments in Automatic Control*. Details: The Secretary, The Institution of Mechanical Engineers, London.

THURSDAY 7 JANUARY 1960
The Production and Assimilation of Meteorological Observations by E. J. Sumner. S.I.T.

MONDAY 11—WEDNESDAY 13 JANUARY 1960
6th National Symposium on *Reliability and Quality Control in Electronics*. Washington. Details: R. Brewer, General Electric Co. Ltd., Wembly, Middx.

WEDNESDAY 13 JANUARY 1960
Discussion on *The Reliability, Maintenance and Serviceability of Computers*. Brit.I.R.E.

MONDAY 18—FRIDAY 22 JANUARY 1960
44th Physical Society Exhibition, Royal Horticultural Society's Halls, Westminster

TUESDAY 19 JANUARY 1960
Discussion on *Superseding the Ratio Arms in A.C. Bridges* (Opened by C. G. Mayo). I.E.E.

WEDNESDAY 20—THURSDAY 21 JANUARY 1960
Managerial and Engineering Aspect of Reliability and Maintenance of Digital Computer Systems. I.E.E.

TUESDAY 26 JANUARY 1960
Symposium on *Flame Failure Detection*. S.I.T.

WEDNESDAY 10—FRIDAY 12 FEBRUARY 1960
Solid State Circuits Conference, Philadelphia. Details: The Chairman, 1960 Solid State Circuits Conference, General Electric Co., Electronics Laboratory, Electronics Park, Syracuse, New York, U.S.A.

THURSDAY 11 FEBRUARY 1960
Measurement, Automatic Control and Data Reduction as Applied to a Cyclic Plant by T. A. Lucas. S.I.T.

WEDNESDAY 17 FEBRUARY 1960
Faraday Lecture—*Electrical Machines* by Prof. M. G. Say. Central Hall, London

MONDAY 22—FRIDAY 26 FEBRUARY 1960
First Engineering Materials and Design Exhibition and Conference. Earls Court

Looking Further Ahead

WEDNESDAY 16 MARCH 1960
The Simulation of a Large Chemical Plant on an Electronic Analogue Computer by A. H. Doveton and K. C. W. Pedder. S.I.T.

SATURDAY 12—MONDAY 21 MARCH 1960
42nd International Trade Fair. Lyons

MONDAY 21—TUESDAY 22 March 1960
Discussion on *The Computer in Production*. I.Mech.E.

TUESDAY 29 MARCH 1960
Application of Transistors in Instrumentation by G. G. Bloodworth. S.I.T.

TUESDAY 5—SATURDAY 9 APRIL 1960
Ninth Electrical Engineers Exhibition. Earls Court.

THURSDAY 7 APRIL 1960
The Electronic Computer as a Unit in an Automatic Electronic Data Processing System for Missile Trials by W. C. J. White and D. L. Overheu. S.I.T.

MONDAY 25—SATURDAY 30 APRIL 1960
Production Exhibition, National Hall, Olympia

TUESDAY 26 APRIL 1960
Control Section Annual General Meeting 6.15 p.m. *Some Recent Advances in Industrial Electrical Control Techniques*. S.I.T.

TUESDAY 3—FRIDAY 13 MAY 1960
Mechanical Handling Exhibition and Convention. Earls Court

MONDAY 23—SATURDAY 28 MAY 1960
Instruments, Electronics and Automation Exhibition, Olympia

FRIDAY 10—SUNDAY 26 JUNE 1960
British Exhibition U.S.A. New York

FRIDAY 24 JUNE—FRIDAY 8 JULY 1960
International Machine Tool Exhibition. London

SATURDAY 25 JUNE—TUESDAY 5 JULY 1960
Moscow Congress for Automatic Control. Details: International Federation of Automatic Control, Prinz-Georg-Strasse 70, Düsseldorf, Germany

THURSDAY 21—WEDNESDAY 27 JULY 1960
Third International Conference on Medical Electronics. Olympia.

MONDAY 5—SUNDAY 11 SEPTEMBER 1960
S.B.A.C. Flying Display and Exhibition. Farnborough

WEDNESDAY 21 SEPTEMBER—SATURDAY 1 OCTOBER 1960
International Factory Equipment Exhibition. Belle Vue, Manchester

WEDNESDAY 19—WEDNESDAY 26 OCTOBER 1960
Interkama International Congress and Exhibition for Instrumentation and Automation. Düsseldorf

PEOPLE IN CONTROL

by Staffman

EADES HARRIS BEVINS ALDINGTON wrong number WRIGHT ROBINSON

On November 10 the new Postmaster General, **J. R. Bevins,** saw the first experimental electronic telephone exchange at the Post Office's Dollis Hill Research Station. He appears in my heading illustration in company with the P.O.'s chief engineer, and directors of four of the five telephone equipment manufacturers who co-operated with the P.O. in producing the new exchange. The exchange will probably go into operation at Highgate Wood in 1961-2. My photograph shows, left to right: **Sir Thomas Eades,** Chairman of the Automatic Telephone

SIMMONDS semiconducts

ELLISON directs

and Electric Co.; **Sir Lionel Harris,** Engineer-in-Chief of the Post Office; the P.M.G.; **J. N. Aldington,** Group Managing Director of Siemens Edison Swan—Associated Electrical Industries (Woolwich) from January 1; **F. C. Wright,** Managing Director of Standard Telephones and Cables; and **R. Robinson,** Director in charge of G.E.C.'s Telephone, Radio and Television Works: **J. H. Mitchell,** Director of Research at Ericsson Telephones—the fifth member of the quinquepartite telephone manufacturing industry—is conspicuous by his absence.

I was surprised to hear that **K. R. Simmonds** had left Texas Instruments to join International Rectifier Co. (Great Britain) Ltd. as General Manager. Both companies are, of course, associated with American firms and both market semiconductors, although Texas's interests lie mainly in the transistor field whilst International Rectifier are more concerned with heavier work. **Lord Halsbury** who, it may be recalled, was N.R.D.C.'s Managing Director, a position he gave up to become Vice Chairman of Lancashire Dynamo, is International's Chairman.

Simmonds tells me that International has moved into a new factory at Hurst Green, Surrey, and will shortly manufacture medium and high power silicon rectifiers and a silicon controlled rectifier of 10 amp at 200 volt rating.

International Rectifier's Engineering

SWINN travels

ANDERSON navigates

Manager is **Peter Ransom** who joined from A.E.I.'s Semiconductor Research Laboratory at Rugby.

Wing Commander **E. W. Anderson,** this year's President of the Institute of Navigation, is Project Manager of Sperry Gyroscope's Bracknell Division. He tells me that 'the main weakness in navigational thinking, particularly on the academic level, is the divorce of the flying control of an aircraft from its positional navigation. There are three servo loops in air navigation,' he said, 'the outer positional loop, the inner steering loop, and—the innermost and shortest term of all—the flying loop. All three should be integrated into a single science'.

Appointed Joint Managing Directors of the long-established electrical switchgear and motor control gear firm, George Ellison Ltd., of Birmingham, are **Thomas G. Ellison** and **Arthur E. Skan.** Ellison, son of the founder of George Ellison Ltd., is also Chairman of the company as well as Chairman of the associated companies, Alfred Ellison Ltd., and Tufnol Ltd. Skan is a Director of all three.

'I have moved from an interest in things to an interest in people' said **D. W. Davison** when I asked him to comment on his transference to Plessey's Central Personnel Executive. Davison, who has been in research and development in industry for twenty years, in both this country and Australia, is to assist Plessey's Personnel Director, **A. M. Brown,** with scientific and technical appointments.

Arthur W. J. Lewis, who is the Labour M.P. for West Ham North, tells me that he has been appointed the East German government's sole purchasing agent for electronic equipment. At the moment he is trying to help them purchase the complete plant and equipment for the factory manufacture of transistors. Another East German requirement is for control and regulating equipment for cement and sugar manufacture.

Formerly Technical Sales Manager of Kelvin & Hughes (Industrial) Ltd., **Herbert Slack** has, at 32, been appointed to the Board as Sales Director. He explained to me the three broad groups into which the products of the Industrial division fall: ultrasonics; high speed pen recording; and industrial measurement and control for small boilers and the plastics industry.

Back from a visit to Spain is Honeywell Controls' **Bill Swinn,** who recently toured steel centres in that country at the invitation of Honeywell's Spanish Associates Omnium Iberico Industrial S.A. Swinn presented a paper on furnace instrumentation.

Electrical Aids in Industry *Data Sheet* **No. 6**

Lighting -1

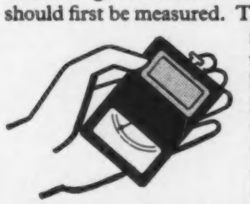
Good lighting affects productivity in three ways, (1) by directly increasing the speed of working and reducing errors and wastage, (2) by improving overall factory efficiency through better supervision and housekeeping, (3) by providing better working conditions, thus improving labour relations and avoiding frequent changes of workpeople.

It is not possible to judge by the eye alone whether the lighting in any factory is good enough to serve these purposes because the eye has a tremendous range of adaptation (vision of some kind is possible within an illumination range of 1,000,000 to 1) and is hence an unreliable measuring instrument. Severe mental and eye strain or unconscious slackening of working speed may occur under lighting which *appears* to be adequate.

The only reliable way to appraise factory lighting is to conduct a lighting survey using a lightmeter, an inexpensive instrument which measures the actual illumination available. These figures can then be compared with official recommended values for the various tasks.

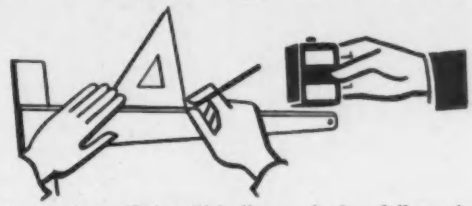
Lighting Survey

A methodically conducted lighting survey is the first step towards achieving good productive lighting. The average artificial illumination at working height should first be measured. This requires a number of readings at various positions relative to the lighting fittings, particularly beneath and between fittings and by the wall. The average of the readings should then be compared with the illumination values recommended by the Illuminating Engineering Society. The following is a general guide to illumination requirements.



NATURE OF WORK, PROCESS OR MATERIAL	ILLUMINATION LUMENS/SQ.FT.
Rough or routine work. Large detail. Medium to light material of good contrast.	7
As above, but work rather more skilled or critical.	10
Ordinary work usually involving workers' inspection. Medium detail and contrast.	15
Fairly critical work, fairly small detail or poor contrast.	20
Skilled work, small detail or dark material.	30
Fine or critical work, very small detail, very poor contrast or very dark material.	50
Very fine exacting work.	100
Minute work.	200

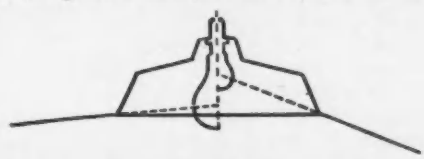
In addition, readings should be taken at selected working points with the lightmeter so placed that it measures the light on the work while the operative



is working. This will indicate whether full use is being made of the light or whether shadow is obscuring part of it.

Glare

Any direct light on the eye tends to reduce its sensitivity—thus reducing the power to see. Increasing the intensity of the light source may



therefore not improve matters unless care is taken to avoid glare either by correct positioning or by the use of correctly matched reflectors and lamps.

Walls and Ceilings

Certain surfaces and certain colours absorb light and therefore do not make the best of a light source; others reflect light and, so to speak, feed back on to the work a portion of the lighting which would otherwise be lost. Bright walls, moreover, have a good psychological effect which makes for contented —and therefore productive—operatives.

Shadows

Unnecessary shadows may seriously slow down work and also cause accidents. Lightmeter readings should always be taken under conditions exactly similar to those obtaining while work is going on. The operative himself may mask his work, an overhead crane or a heavily loaded conveyor belt may periodically obscure a light fitting, or a dust-laden atmosphere may reduce the designed lighting values.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books are available on electricity and productivity (8/6 each or 9/- post free)—"Lighting in Industry" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity including one on industrial lighting. Ask for a catalogue.

Tick No 99 on reply card for further details

New for Control

A monthly review of system components and instruments

DIGITAL RECORDER

with up to 288 channels

A recent multi-channel digital millivolt recorder is designed to record multi-channel strain gauge or thermocouple outputs, and will give a full scale decimal digital output for inputs ranging from 15 to 50 mV recorded on a Creed tape-punch or an IBM electric typewriter. Single outputs may be fed to an illuminated numerical display.

The equipment is rack-mounted in a substantial cabinet 3 ft 6 in. high. Unit construction is used throughout and the rack contains the display unit, channel selectors, digitizer chassis, control unit, output unit and power unit.

The multi-channel digital millivolt recorder is manufactured by Bristol Aircraft Ltd., and distributed by Southern Instruments Ltd.

Tick **No 251** on reply card

ACCELEROMETER

high performance, low cost

The MV 300 accelerometer is available in a selection of models whose sensitivities range from 0·5 to 8·0 V/*g* when working into a 0·5 megohm load, with natural frequencies from 137 to 34 c/s. The full scale output is 25 V.

The overall hysteresis is less than 0·7% of the amplitude, and cross-coupling errors are less than 0·2%. Stops capable

Full scale output is 25 V

of withstanding high shock loads and sustained overloads of the order of 100 *g* are fitted.

The maximum zero error is 1·5% of full scale and its maximum temperature coefficient is 2·5 mV/°C. Normally a sensitivity tolerance of ± 5% is adequate, but for special purposes this figure can be exceeded. The temperature coefficient of sensitivity is less than 0·2%/°C.

The weight is 94 g and the dimensions are 1·3 × 1·1 × 1·7 in. The supply is 115V 2·4 kc/s.

The manufacturers are de Havilland Propellers Ltd.

Tick **No 252** on reply card

FREQUENCY METER

speeds up to 300,000 rev/min

The frequency meter (type 265) is a small, light, transistorized instrument which may be operated from internal batteries or an a.c. mains supply. Its range is 10 c/s to 100 kc/s, and the accuracy over most of the range is ± 5% f.s.d. Inputs signals may be of any amplitude between 0·075 and 30 V r.m.s.

An optical probe (type 283) is available for use with the frequency meter, and in this way the meter may be employed as an electronic tachometer. The frequency range of the probe is from 5 c/s to 5 kc/s, this latter frequency corresponding to shaft speed of 300,000 rev/min when there is only one transition from light to dark per reduction. With a shaft painted black and white the maximum operating distance is 5 in.

Tick **No 253** on reply card

SIMULATOR

for nuclear reactors

A nuclear reactor analogue simulator has been designed which can simulate a thermal or a fast fission reactor running at low power throughout its power range up to a level of 100 kW. The five groups of delayed neutrons associated with the fuels uranium 235, 233 or plutonium 239 can be reproduced. An additional theoretical fuel, uranium 235/2, illustrates a two-group treatment of delayed-neutron effects and emphasizes the effect of delayed neutrons on reactor control.

Provision for the study of automatic control systems, and the calculation of changes in reactivity due to the fission product poisoning, temperature coefficient and thermal transient effects can be incorporated to suit any requirement.

In association with the simulator a reactor core model represents a cross-section of a typical graphite-moderated nuclear reactor, complete with fuel elements, control and safety rods. The model displays an illuminated pictorial representation of changing conditions within the reactor core. It is automatically linked to the simulator and operates in synchronism with its corresponding controls, or alternatively it can be individually operated.

The simulator (Mk. 1) costs £3100, without the reactor core model, and is manufactured by Vickers-Armstrongs Ltd.

Tick **No 254** on reply card

TEMPERATURE CONTROLLER

for heating systems

An automatic boiler-temperature controller from Samson Controls uses two thermostats, integrally connected in one system filled with a liquid having a coefficient of expansion. One thermostat is fixed in the open air and the other is connected into the boiler or boiler flow stream. The thermostats work in conjunction with one another. Simple controls

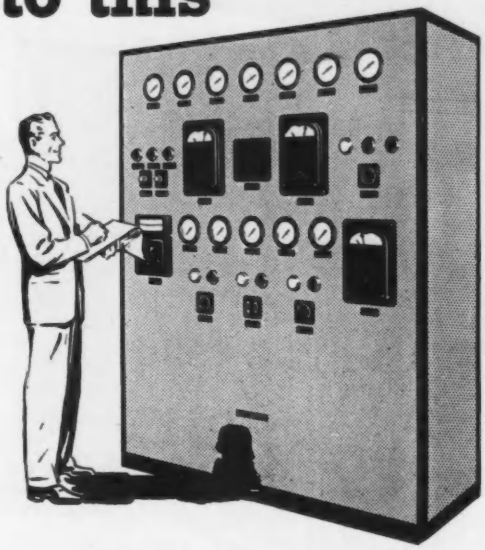
Cheap, well-made

are provided for setting the desired boiler temperature and any combination of open air/boiler flow temperatures can be accommodated. A manually-operated switch, marked 'day' and 'night', provides an automatic lowering of the boiler temperature through the night.

The capillary tube connecting the outside thermostat to the unit is compensated so that it is unaffected by the temperature of either the boiler room or any other space through which is passes. This

From this

to this

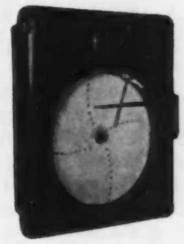


and everything between!

A single thermometer to a complete installation. We produce a wide range of industrial indicating, recording and controlling instruments. Our service includes a contracts department for the engineering and installation of complete instrumentation schemes.

Brass-cased tank and pipe thermometer

Mercury-in-steel dial thermometer, distance-reading type



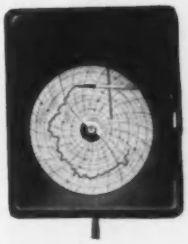
Disc chart pressure recorder

10" multipoint pyrometer indicator

Air-operated mercury-in-steel temperature transmitter

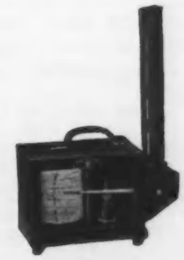
Air-operated compound controller

Dial Pressurestat



"Mersteel" recording thermometer

Valve positioner



Recording hair hygrometer

INSTRUMENTATION BY—

NEGRETTI & ZAMBRA

NEGRETTI & ZAMBRA LIMITED 122 REGENT STREET, LONDON W1

Manufacturers of instruments for the indication, recording, controlling of:— temperature, pressure, liquid level, volume, specific gravity, humidity, etc. Also meteorological and aircraft instruments.

Tick No 100 on reply card for further details

tube is plastic-covered and is available in lengths of 18, 36 or 72 ft.

This unit is available in two models, one to control the automatic burner of an oil fired boiler; and the other, complete with electric motor, connecting chains, etc., to control the settings of the flue and boiler dampers of a solid-fuel boiler. The prices are £26 4s for the former and £36 18s for the latter, both with 18 ft of capillary tube.

Tick **No 255** on reply card

HYDRAULIC VALVE

for the die-casting industry

The Sinclair-Collins four-way cylinder-operated hydraulic valve is now available from Hunt & Mitton. It will handle pressures up to 3000 lb/in², and can be used with a single or double solenoid pilot-operated Speed King control valve. The valve comes in three sizes—1, 1½ and 2 in.; and uses air pressures of 60 to 125 lb/in² for a power source.

The valve was designed for the die-casting industry where water is often used as a hydraulic medium in casting machines. Diaphragm valves are too slow, and a four-way valve such as this one is needed that will not reverse itself if a supply fails.

Tick **No 256** on reply card

DATA PROCESSING

using a new computer

IBM United Kingdom Ltd. have announced details of the fully transistorized 1620 data-processing system, a small but powerful stored-programme computer designed for complex scientific engineering work.

The IBM 1620, which can perform over 100,000 calculations a minute, consists of a central processing unit, paper tape reader and punch. The storage consists of 20,000 decimal digits of immediate-access magnetic-core storage with variable field and record length. In addition to paper tape there is also direct input-output by console typewriter.

Programming for the IBM 1620 is simplified by the availability of two advanced programming systems including the IBM Fortran system, and a comprehensive library of mathematical and statistical routines.

Tick **No 257** on reply card

Two men at work with the IBM 1620 data processing system

MAGNETIC AMPLIFIER

for use with size 18 motors

High-power magnetic amplifier (type R603) is designed for use with a size 18 servomotor. It is hermetically sealed, and is made to the general requirements of MIL-T-27 by R. B. Pullin & Co. Ltd.

A reversible d.c. input signal is needed, which is amplified and provides a phase reversible a.c. output to the control phase of the servomotor. Output voltage is in quadrature with the excitation. Model RH603, with similar electrical characteristics, is available on special order to operate up to 125°C.

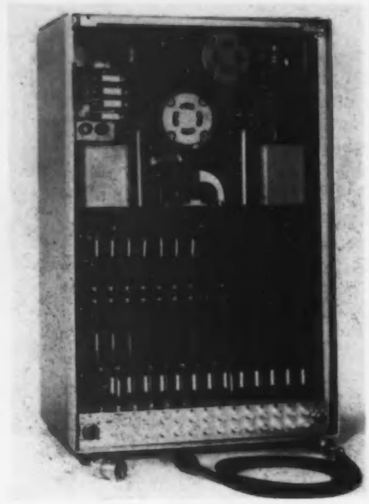
The characteristics of the amplifier are as follows: frequency 400 c/s; primary voltage 115 V; rated load impedance (tuned for unity power factor) 775 ohms; power output (into rated load) 18 W; voltage output (into rated load) 155 V; primary current (at rated output) 0·400 A; quiescent control coil current 4 mA/coil; control coil resistance 5600 ohms/coil; magnetic amplifier tuning capacitor 1·0 μF (in addition to capacitor required to tune load for unity power factor); recommended control coil by-pass capacitors 0·1 μF; ambient temperature ranges: R603 −55°C to +71°C; RH603 −55°C to +125°C.

Tick **No 258** on reply card

TAPE RECORDER

for 14 channels

A 14-channel portable magnetic tape recorder weighing 100 lb has been developed by Precision Instrument Co. Based on the company's seven-channel model, the PS-214 recorder/reproducer measures



About 7 lb/channel

16½ × 25¼ × 14 in. Completely transistorized, the PS-214 features modular construction and printed circuit boards to allow the interchange of any number of direct or FM channels up to 14. It has magazine-loading for rapid replacement of tape or substitution of a continuous loop magazine. Only 5 sec are required to change magazines. Any number of the PS-214's available tracks can be used for high-frequency recording, low-frequency data, transient phenomena, and quasi-static measurements. A variety of data can be recorded concurrently with a common time base. Six speeds are available by means of push button selectors and belt changes.

Further information is available from B. & K. Laboratories Ltd.

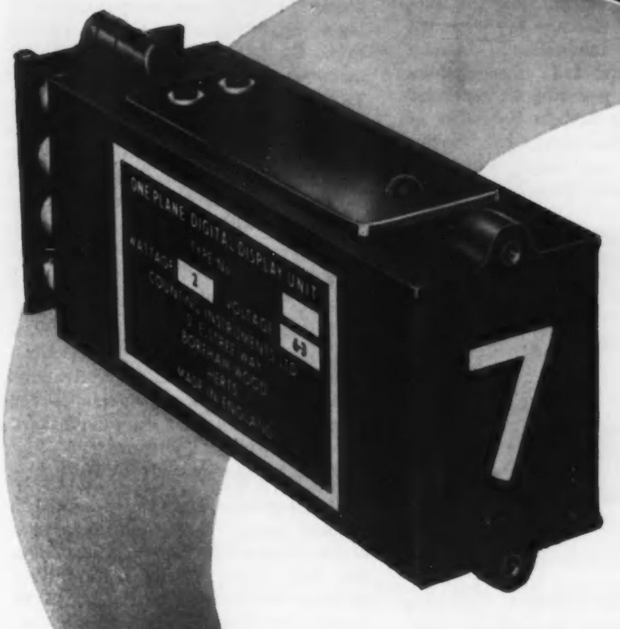
Tick **No 259** on reply card

POWER SUPPLY

specially for strain gauges

A fully transistorized six-channel strain gauge power supply (type AS 958) is now available from the Solartron Electronic Group Ltd. When working from transducers into a high-gain amplifier a normal stabilized power supply may produce a large amount of unwanted mains hum. To overcome this the AS 958 uses special transformers so that undesirable feed-through is reduced to a figure of less than 0·1% of full-scale output. The unit has been designed to work into bridges of a nominal 350 ohms resist-

THE FINEST PROJECTION TYPE IN-LINE DISPLAYS FEATURING ONE-PLANE PRESENTATION



Here are two new type In-Line Displays with all the features you have been looking for, now available with 1" or 5/8" illuminated figures. All numbers, characters, and data appear on the front surface of the unit, and are uniform in size and intensity. In addition to being faster and easier to read, the information may be quickly seen from any viewing angle. Designed as a single unit, the In-Line Display may be assembled in any desired grouping, presenting a continuous surface for fast, easy reading.

ASSEMBLY

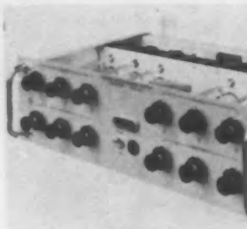
The In-Line Display Units are available in groups of two or more with bracket ready for fast, easy panel mounting. Assemblies are provided with continuous viewing screen for utmost legibility and eye appeal.

BRACKET
Special mounting bracket now available for fast, easy reading.

Counting Instruments Ltd

COUNTING INSTRUMENTS LTD. 5, ELSTREE WAY, BOREHAM WOOD, HERTS.

Telephone: ELStree 1382 (4 lines)



Minimum hum

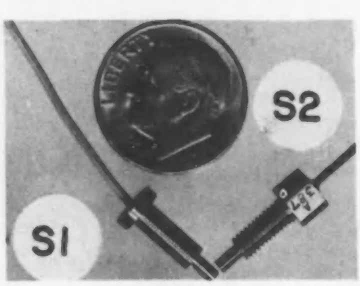
ance, but may also be used with resistance bridges of higher impedance. The power supply incorporates six individual, fully-floating stabilized power sub-units. Each sub-unit is capable of providing a nominal 5 V of regulated d.c. at up to 20 mA. A sensitivity control allows variation of the output voltage by $\pm 5\%$. Also incorporated is a balance control capable of correcting initial bridge unbalance of up to 10% of full-scale.

Tick No 260 on reply card

TEMPERATURE SENSORS

transients up to 100,000 lb/in^2

Two unique temperature sensors, called Delta-couples, are manufactured by Advanced Technology Laboratories. They are designed to indicate rapidly changing surface temperatures of steel structures over a wide range of pressures and temperatures, and are offered with nickel-steel thermocouple junctions at either 0·0002 in. below the surface of interest for maximum response, or at 0·002 in. below the surface where abrasion is a consideration. Two basic models are now available. The S1 was developed to with-



Dime-size!

stand extremely high pressures, such as those experienced in gun chambers, while the threaded body of the model S2 facilitates simple installation. Developed after years of experience in instrumenting high-energy, high-velocity guns, the sensors have successfully experienced repeated transient pressures of 100,000 lb/in^2 and transient temperatures in excess of 2100°F. Rugged in design and precise in response, these units are claimed to be well suited for instrumentation of gun bores, rocket motors, internal combustion engines, bearings, and process industry apparatus, and wherever rapidly fluctuating surface temperatures are experienced.

Tick No 261 on reply card

SOLAR BATTERIES

of high efficiency

High-efficiency silicon solar battery modules are now available to provide the same power output, watt for watt, as dry cell and mercury cell batteries. Available from International Rectifier Co. (Great Britain) Ltd., these modules are designed for powering transistorized equipment during daylight operation, as well as for charging storage batteries for continuous day and night operation. Applications include power supplies for

Sunlight power

transistorized radios, telemetering and control circuitry, and numerous communication equipment uses.

The output voltage of the solar module is 1·75 V at 30°C cell temperature, and 1·5 V d.c. at 65°C (typical operating temperature in direct sunlight). Direct replacement may be achieved by substituting one SM5-1020B module for each 1·5 V dry cell battery, and using as many parallel strings as required to supply the necessary load current. Each module will supply a load current of approximately 35 mA in direct sunlight.

Tick No 262 on reply card

QUICK LOOKS

The AS 870 is a new addition to the range of stabilized transistor power supplies made by Solartron. Maximum output is 30 V at 3 A, and high stability and comprehensive overload protection are claimed.

Tick No 263 on reply card

An indication of power-house efficiency, in addition to assistance in the control of harmful grit emission, is obtained by the use of a flue dust monitor. Dust concentration is determined by means of a density wedge in a light beam, operating a photo-transistor. A second identical transistor is used to provide reference, and both transistors are coupled to a differential relays in the control unit.

The instrument operates continuously, and records measurements at pre-set periods on a 24 h chart. The monitor (the 'Eel') is manufactured by Evans Electro-selenium.

Tick No 264 on reply card

A series of *n-p-n* 60 V 6 A germanium alloy transistors has been introduced by Sylvania-Thorn Colour Television Laboratories Ltd. Designed for power switching applications the new series is claimed to be the only one of its type hitherto manufactured in this country.

Tick No 265 on reply card

A tape deck driven by three shaded-pole motors may be useful for use with control equipment. It has electrical and mechanical brakes which enable fast rewind times without undue stretch. The frequency response of the head is 30 c/s to 17 kc/s at 7½ in/s.

Tick No 266 on reply card

A high-precision dial test indicator is now being distributed by Optical-Mechanical (Instruments) Ltd. Readings to an accuracy of one micron over a range of 2 in. are claimed by the makers, Hahn and Kalb of Stuttgart.

Tick No 267 on reply card

EMI Electronics Ltd. has produced a compact monitor for monitoring radioactive contamination on benches, clothing, and similar objects. All-transistor circuitry enables the instrument to be operated for long periods from a battery supply.

Tick No 268 on reply card

For sensitive control circuits B. & R. Relays are making a transistorized amplifier which may be integrated with their relay assemblies. One to three stages of amplification are obtainable, depending upon the input signal level; units are suitable for a wide range of ambient temperature.

Tick No 269 on reply card

The range of miniature timers (type MSC) manufactured by Electrical Remote Control Co. Ltd. has been extended. New timers (type ZX) have a switching capacity of 15 A at 230 V a.c. or 3 A at 440 V a.c. They can be supplied with up to twelve change-over switches.

Tick No 270 on reply card

A Swiss tension gauge is being marketed by James W. Carr. Eleven models are available, to cover from 0·3–2000 g, most of which have a maximum tension indicator.

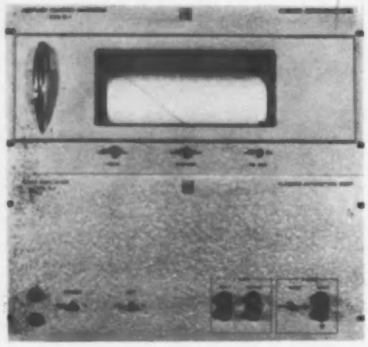
Tick No 271 on reply card

High-vacuum distillation of heat-sensitive substances, carried out below their normal boiling point, offers fewer hazards than other methods. A 2in. vacuum still is suitable for experiment

and small-scale production: full specification is obtainable from the makers, Edwards High Vacuum Ltd.
Tick No 272 on reply card

A range of standard racks is made by Lunds from 10-gauge formed steel sections, finished in hammered stove enamel. They are made to a depth of 19 in. for standard panel mounting, and hinged rear door and quick-release side panels make for easy accessibility.
Tick No 273 on reply card

A range of chokeless power supply subunits has been produced by the Solartron Electronic Group. These are designed for continuous-duty pulse loading applications, with pulsing controllable from zero to full load. The stability factor is better than 400:1, and the units enable a low source impedance to be held up to 0·5 Mc/s.
Tick No 274 on reply card



This function generator (type SF-1) has an X-axis response time of approximately one second for f.s.d. It generates arbitrary functions using a servo system. Made by Alabama Automation Corporation.
Tick No 275 on reply card

New models of multi-stage non-synchronous timers are being made by Lancashire Dynamo Electronic Products, for incorporation into resistance welding machines. Units are in production for various control sequences, all including single or repetitive spot operation.
Tick No 276 on reply card

The impulse relay (type 596) is the latest addition to the Magnetic Devices range. Direct current impulses to the relay will alternately operate and release the spring set on one side of the relay, whilst the contacts on the other side will follow the armature. In the open version up to two change-over contacts can be supplied on each contact stack.
Tick No 277 on reply card

A silicon controlled rectifier is in pre-production at A.E.I. The device is of *p-n-p-n* form, and may be regarded as two transistors coupled by a common collector junction; it is the solid-state equivalent of the thyratron or the grid-controlled mercury-arc rectifier. It is of small size, and a high efficiency of operation is claimed. Maximum rating available is 10 A at 300 V peak inverse voltage.
Tick No 278 on reply card

An instrument providing logarithmic attenuation of pulses before amplification is to be marketed this year. Constant accuracy throughout the spectrum and better comparison of intensities is claimed for the unit (model PW4073) by the distributors, Research and Control Instruments.
Tick No 279 on reply card

Small size and low torque are two features claimed by Smiths Aviation Division for its 360-degree counter, which indicates angular rotation by three-figure presentation. It is claimed to be smaller than any other of the same type, and fits into a space 1·20 × 1·33 × 0.81 in. Half-degree divisions should make it possible to read to an accuracy of ¼°.
Tick No 280 on reply card

A range of square-flange moving-coil d.c. meters is being made by Sangamo Weston in three dial sizes. The basic range on all sizes is 25 μA f.s.d. Models are S219, S220, S221 and S236.
Tick No 281 on reply card

A v.h.f. signal generator from Airmec has a wide frequency range, extending from 1 to 320 Mc/s. Provision is made for modulation from internal or external sources, including external pulse modulation.
Tick No 282 on reply card

A building block (model 91) has been added to the range of pneumatic gauging equipment made by Teddington Industrial Equipment Ltd. The unit provides a complete pneumatic gauging circuit which, when necessary, can be connected to a size indicator. In this way a multi-dimensional gauging circuit can be made simply by building up these blocks round a central size indicator.
Tick No 283 on reply card

Research and Control Instruments Ltd. are marketing a Philips variable transformer which has separate primary and secondary windings. It is available in two versions for bench use or for panel mounting. The nominal secondary current is 1·5 A and the output rating is 450 VA.
Tick No 284 on reply card

Our attention has been drawn by Amphenol (Great Britain) Ltd., to an error in 'Quick Looks', November issue. A picture of one of their Borg microdials (described in the first item) was incorrectly shown as the window-turns counter of General Controls. We apologize for any confusion that this error may have caused.

INDUSTRIAL PUBLICATIONS

A data sheet from Solartron describes their digital data recorder.
Tick No 285 on reply card

Beckman Instruments have a short but comprehensive leaflet on Helipot precision potentiometers.
Tick No 286 on reply card

Also from Beckman, a data sheet shows turn counting dials for use with helical potentiometers, etc.
Tick No 287 on reply card

General purpose diode function generator is shown in a Solartron data sheet.
Tick No 288 on reply card

Data of an X-ray spectrometer with continuous scan, and needing a minimum of calibration, from Solartron.
Tick No 289 on reply card

For basic training, an analogue tutor is briefly described by Solartron.
Tick No 290 on reply card

Instruments by Kent for temperature measurement are shown in their publication No. 265.
Tick No 291 on reply card

A bulletin from N.S.F. shows printed circuit connectors.
Tick No 292 on reply card

Descriptive leaflet and data sheets (No. 5076) from de Havilland on portable automatic cable tester.
Tick No 293 on reply card

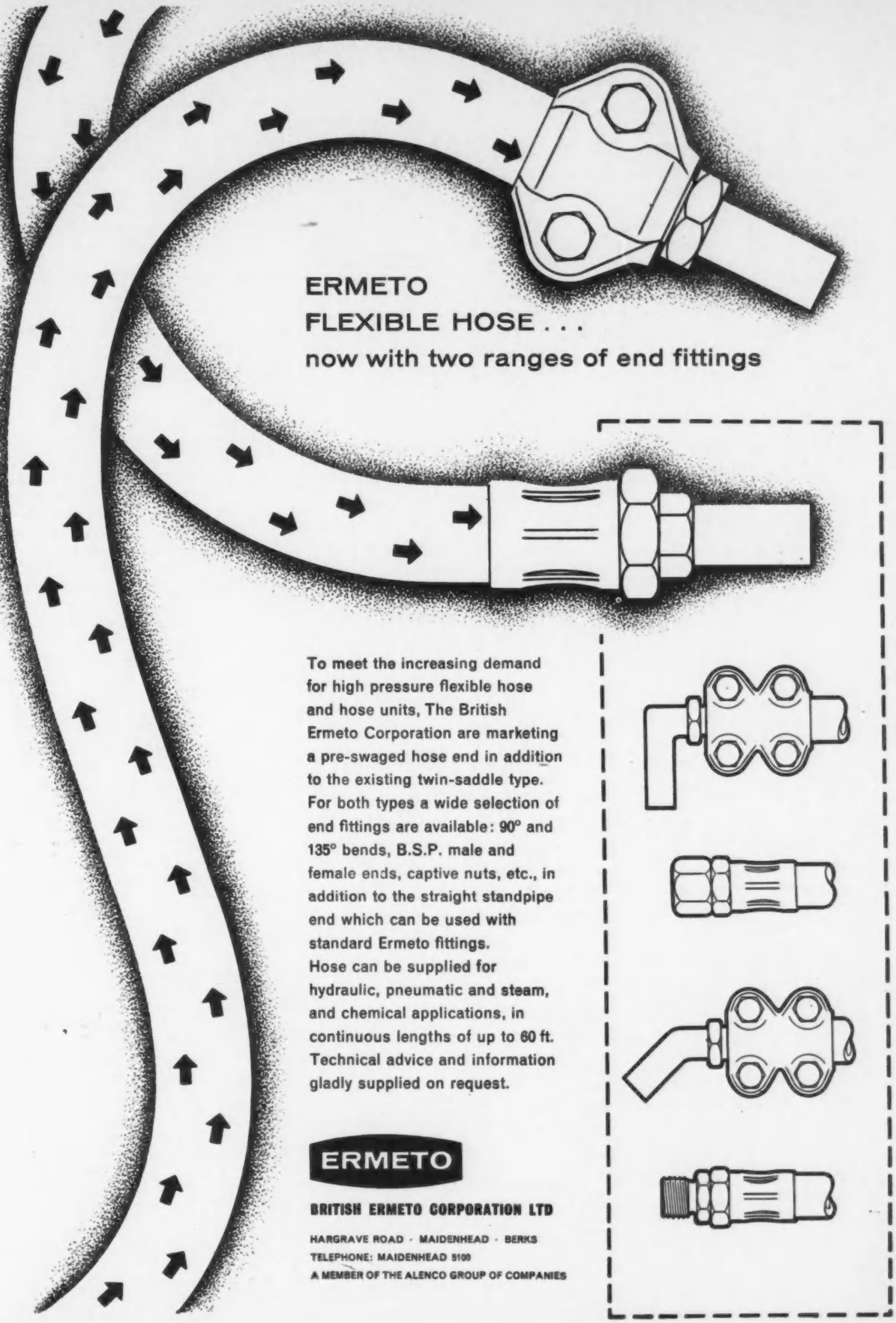
Also from de Havilland data sheets on electromechanical torque motors (Publication No. 5078).
Tick No 294 on reply card

Equipment for humidity control is shown in a twelve-page pamphlet from Negretti and Zambra.
Tick No 295 on reply card

A well illustrated general catalogue from Muirhead.
Tick No 296 on reply card

A brief description of a transistor curve tracer comes from de Havilland.
Tick No 297 on reply card

First of a quarterly series, a Review of Radio and Electronics, including details of new ranges, is issued by Siemens Edison Swan.
Tick No 298 on reply card



ERMETO FLEXIBLE HOSE . . .

now with two ranges of end fittings

To meet the increasing demand for high pressure flexible hose and hose units, The British Ermeto Corporation are marketing a pre-swaged hose end in addition to the existing twin-saddle type. For both types a wide selection of end fittings are available: 90° and 135° bends, B.S.P. male and female ends, captive nuts, etc., in addition to the straight standpipe end which can be used with standard Ermeto fittings. Hose can be supplied for hydraulic, pneumatic and steam, and chemical applications, in continuous lengths of up to 60 ft. Technical advice and information gladly supplied on request.

ERMETO

BRITISH ERMETO CORPORATION LTD

HARGRAVE ROAD · MAIDENHEAD · BERKS
TELEPHONE: MAIDENHEAD 5100
A MEMBER OF THE ALENCO GROUP OF COMPANIES

Tick No 103 on reply card for further details

For your bookshelf

Classic for beginners

Servomechanisms and Regulating System Design, Volume 1, *by* **Harold Chestnut** *and* **Robert W. Mayer.** *Wiley. 1959. 680 pp. £4 14s.*

Here is a second edition of what has come to be regarded as something like the classic text-book in this field. The first edition has been going for quite some years now, and it is interesting to see what the authors think has been teachably added to the subject. In this edition they seem to ascribe the greatest importance to the root locus method and analogue computery, since new chapters have been added on these matters. Other changes include the use of ASA C-85 terminology, a revised account of error coefficients, new emphasis on loading interaction, and more material on prediction of transient closed-loop response from the open-loop frequency response.

One cannot feel unhesitatingly assured that the complete newcomer to control design will be as well served by this admittedly excellent book as the blurb on the dust jacket suggests. The introductory chapter, for example, involves a degree of abstraction that may make it a little tough for the tyro. Occasionally, too, the reader stubs his toe against an unhappily written phrase. One instance occurs on page 597, where we are told that 'it is common practice to hand, or digital computer, calculate the exact solution for a nominal condition.'

The mathematical treatment, as in the first edition, does begin at quite an early stage, and this is a distinct merit.

E. M. JAMIESON

Outline favourable

Electronic Engineer's Reference Book *edited by* **L. E. C. Hughes.** *Heywood. 1959. 1588 pp. £4 4s.*

It is a bad review that is merely an inflated list of contents, but sometimes I feel that not much more is possible. A conscientious reviewer, faced with yet another fat work of reference, is bound to wonder how far he is required to go. Surely he cannot be expected to read minutely through all this? If he is, and if he does the job with any thoroughness, then the later editions of the work will be rolling off the presses before he is finished. For his review to be useful—that is, in warning people off or encouraging them to buy—the critic must be quick in his assessment as well as accurate; a difficult task to perform with justice.

Here is a second edition of a reference book of which the first edition is stated to have sold out within nine months of publication. The major sections deal with 'Fundamentals' (which seem to include such matters as archaeological dating and photo-electric greyhound-race timing), 'Radiations,' 'Electrics' (embracing a range of subjects from electrons in metals to electronics in medicine), 'Valves,' 'Materials,' 'Vibrations,' 'Computing,' and 'Automatics.'

I confess that I am not conscientious enough to read through the whole of this volume before writing a review. Instead I propose to do a little random sampling. Spontaneously, I think of two fields, fundamental measurement and cybernetics. What can I find about them in this book? Surely enough, in the section entitled 'Fundamentals,' I discover a sub-heading 'Fundamental Measurements.' This is sub-divided into four parts, labelled respectively *Temperature, Atomic and Astronomical Time, Colour,* and *Metric System.* Without anything very strongly in view, I turn to the last-named and find it to consist of less than two pages, partly devoted to the folly of our monetary units. 'Cybernetics,' alas, does not show up in the index, so I turn to the section called 'Automatics.' (The list of contents names this section, but does not tell me on what page it starts. However, I find it at last.) Here the word 'cybernetics' emerges in the first few lines of the first page. The section itself has about 150 pages of quite interesting and well-presented material.

Random sampling gives spot results; what is the overall impression? Generally favourable, though the reference numbering is rather confusing.

A.E.E.

Ready for the worst

Design of Transistorized Circuits for Digital Computers *by* **A. I. Pressman.** *Chapman & Hall: London. Rider: New York. 1959. 316 pp. £4.*

It is possible to study the logical design of digital computers in an abstract way, using idealized elements and mathematical aids such as Boolian algebra. In this way much good has come to the subject, since studies of this kind enable the underlying organizational problems of computer construction to be separated from the engineering problem of how to make things work. They can, however, never do more than provide a background for the practising engineer charged with the design of an actual computer; his preoccupation is with the characteristics of the components available to him, and with getting the best out of them as regards economy and speed of operations. Naturally the problems facing a designer depend on the type of logical element he intends to use. This book discusses the design of computer circuits in which transistors and diodes are used for performing all logical operations; other elements such as magnetic cores are not discussed.

Although the author says that the book is intended for, among others, those who have no prior knowledge of either transistor or computer-type circuits, it is concerned very much with the details of engineering design and is packed full of quantitative information and examples of design calculations. The emphasis throughout is on 'worst case' design techniques, that is, on the design of circuits which will operate when all the component parameters and applied voltages are at the most unfavourable extremes of their tolerance ranges.

The book will not provide light reading for those who have a general concern only with computer circuits, but should be of great interest to anyone engaged in the design of digital circuits either for computers or for use in control systems.

M. V. WILKES

Books received

Circuit Theory of Linear Noisy Networks *by* **H. Haus** *and* **R. Adler.** *Chapman & Hall. 1959. 79 pp. £1 16s.*

Electro-Technology for National Certificate Courses *by* **H. Buckingham** *and* **E. M. Price.** *English Universities Press. September 1959. 361 pp. 16s.*

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Science in Industry—Policy for Progress *by* **C. F. Carter** *and* **B. R. Williams.** *Oxford University Press. 186 pp. £1 1s.*

Automatic Control in Soviet Industry*. *Department of Scientific & Industrial Research 1959. 64 pp.*

*Reviewed in this issue of CONTROL, page 102.

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W

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Y

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Z

ZEAL LTD., G. H.
Lombard Rd., Morden Rd., Merton, S.W.19 tel: Liberty 2283

ZENITH ELECTRIC CO. LTD., THE
Zenith Works, Villiers Rd., Willesden Green, London, N.W.2 tel: Willesden 6581

BUYERS' GUIDE—CLASSIFIED SECTION

ACCELEROMETERS—linear
★ *Circle No.* 367
Aveley Electric
British Arca Regulators
B. & K. Labs.
Bryans Aeroequipment
Cambridge Instrument
C. F. R. Giesler
De Havilland Propellers
EMI Electronics
Ferranti
G.E.C.
Graseby Instruments
I.E.C.-Sieger
Kelvin & Hughes
Langham Thompson, J.
Louis Newmark
Mechanism Ltd.
Plessey Co.
S.E. Laboratories
Servo Units
Southern Instruments
Sperry Gyroscope
Technical Ceramics

ACCELEROMETERS—rotational
★ *Circle No.* 368
Armstrong Whitworth Equip.
B. & K. Labs.
Hendrey Relays
Louis Newmark

ACCUMULATORS, electric. See **Cells, electric**

ACCUMULATORS, hydraulic—hydro-pneumatic, non-separator
★ *Circle No.* 369
Baldwin Industrial Controls
Electro-Hydraulics
H.M.L.
Joseph Lucas (H & C)
Lockheed Precision Products

ACCUMULATORS, hydraulic—hydro-pneumatic, piston
★ *Circle No.* 370
Baldwin Industrial Controls
Bell Precision
Dowty Equipment
Electro-Hydraulics
H.M.L.
Joseph Lucas (H. & C.)
Industrial Hydraulics
Keelavite Hydraulics
Lockheed Precision Products
Pratt Precision
Short Bros. & Harland
Smiths Jacking Systems

ACCUMULATORS, hydraulic—hydro-pneumatic, flexible separator
★ *Circle No.* 371
Electro-Hydraulics
Fawcett Preston
H.M.L.
Joseph Lucas (H. & C.)
Lockheed Precision Products

ACCUMULATORS, hydraulic—spring-loaded
★ *Circle No.* 372
Electro-Hydraulics
H.M.L.
Joseph Lucas (H. & C.)

ACCUMULATORS, hydraulic—weight-loaded
★ *Circle No.* 373
Electro-Hydraulics
Fawcett Preston
H.M.L.
Joseph Lucas (H. & C.)
Tangyes

ACTUATORS, electric motor. See also **Motors, electric servo**

ACTUATORS, electric motor—linear
★ *Circle No.* 374
A. Schrader's Son
Automa Engineering
Electro-Magnetic Control
English Electric
Evershed & Vignoles
George Kent
Hartley Electromotives
Limitorque Valve Controls
Louis Newmark
Miles-Hivolt
Plessey Company
Sauter Controls
Sperry Gyroscope
Stewart Aero Supply
Teddington Ind. Equip.
Teleflex Products
Western Mfg.
Woden Transformer

ACTUATORS, electric motor—rotary
★ *Circle No.* 375
Drayton Regulator
English Electric
Evershed & Vignoles
George Kent
Honeywell Controls
Louis Newmark
Limitorque Valve Controls
Miles-Hivolt
Plessey Co.
Sauter Controls
Servo Units
Stewart Aero Supply
Teddington Ind. Equip.
Western Mfg.

ACTUATORS, electric solenoid—linear
★ *Circle No.* 376
Automa Engineering
Brookhirst Igranic
B. & R. Relays
Dunlop Rubber
Electran Coil
Electro-Hydraulics
Electro Methods
H. & B. Precision Eng.
John Morris Elec. Eng.
Magnet Devices
Magnetic Controls
Miles-Hivolt
Oliver Pell
Phillips Control (G.B.)
Sauter Controls
S.E. Laboratories
Stewart Aero Supply
Teddington Ind. Equip.
Teledictor
Western Mfg.
Westool
Williams (B'ham), R. A.

ACTUATORS, electric solenoid—rotary
★ *Circle No.* 377
Chilton Electric
Dunlop Rubber
Electro-Hydraulics
H. & B. Precision Eng.
Miles-Hivolt
N.S.F.
Oliver Pell
Stewart Aero Supply
Teddington Ind. Equip.
Western Mfg.
Westool
Williams (B'ham), R. A.

ACTUATORS, hydraulic. See also **Motors, hydraulic servo**

ACTUATORS, hydraulic—linear
★ *Circle No.* 378
Armstrong Whitworth Equip.
Automa Engineering
Baldwin Industrial Controls
Bell Precision
Boulton Paul Aircraft
British Arca Regulators
Cattermole, H. S.
Dowty Equipment
Dowty Hydraulic Units
Drayton Regulator
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Evershed & Vignoles
Exactor
Fawcett Preston
Fairey
Fisher Governor
H.M.L.
Hobson, H. M.
Hydraulics & Pneumatics
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Lockheed Precision Products
Martonair
Maxam Power
Miles-Hivolt
Pratt Precision
Reavell-Fahie
Short Bros. & Harland
Smith & Sons (England), S.
Smiths Jacking Systems
Spenborough Engineering
Sperry Gyroscope
Stein Atkinson
Stewart Aero Supply
Stuart Davis
T.A.L. Numatics
Tully Engineering
Youngs

ACTUATORS, hydraulic—rotary
★ *Circle No.* 379
B. & P. Swift
Cattermole, H. S.
Chamberlain Industries
Dowty Hydraulic Units
Electro-Hydraulics
Exactor
Fairey
H.M.L.
Hobson, H. M.
Isenthal
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Lockheed Precision Products
Miles-Hivolt
Muirhead
Reavell-Fahie
Sperry Gyroscope
Stein Atkinson
Stewart Aero Supply
Tully Engineering

ACTUATORS, pneumatic. See also **Motors, pneumatic servo**

ACTUATORS, pneumatic—linear
★ *Circle No.* 380
Automa Engineering
Air Automation
Bailey Meters & Control
Baldwin Industrial Controls
Bell Precision
Benton & Stone
British Arca Regulators
Consolidated Pneumatic
Crosby Valve & Eng.
Drayton Regulator
Dunlop Rubber
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Elliott Brothers
Fisher Governor
Foxboro-Yoxall
George Hughes
George Kent
Globe Pneumatic Eng.
Graseby Instruments
Honeywell Controls
Hunt & Mitton
Hydraulics & Pneumatics
James Gordon
Lang Pneumatic
Martonair
Maxam Power
Midland Pneumatic
Miles-Hivolt
Nickols Automatics
Plessey Co.
Sauter Controls
Stewart Aero Supply
Stuart Davis
T.A.L. Numatics
Tangyes
Westinghouse Brake

ACTUATORS, pneumatic—rotary
★ *Circle No.* 381
Automa Engineering
Bailey Meters & Control
Dunlop Rubber
Electro-Hydraulics
Globe Pneumatic Eng.
James Gordon
Kinetrol
Limitorque Valve Controls
Miles-Hivolt
Nickols Automatics
Plessey Co.
Stewart Aero Supply

AIR CONDITIONING SYSTEMS—aircraft
★ *Circle No.* 382
Armstrong Whitworth Equip.
H.M.L.
Miles-Hivolt
M.L. Aviation Company
Normalair
Plannair
Stewart Aero Supply

AIR CONDITIONING SYSTEMS—industrial
★ *Circle No.* 383
Automation Systems
Aeraspray Associated
Birfield Industries
Birlec
B.M.B. Sales
Elliott Brothers
Electroflo Meters
Fuel Efficiency
G.E.C.
Harris Eng.
Hirst Electronics
Holmes, W. C.
Honeywell Controls
Int. Engineering Concess.
Mancuna Engineering
Matthews & Yates
Plannair
Reynolds & Branson
South London Elec. Equip.
Sturtevant Eng.
Supervents
Teddington Ind. Equip.
Visco Engineering
Wallace & Tiernan

AIR CONDITIONING SYSTEMS—marine
★ *Circle No.* 384
Birlec
Brush Electrical
Teddington Ind. Equip.
Visco Engineering
Wallace & Tiernan

AIR COMPRESSORS, instrument. For cooling see **Blowers**. For power see **Power packs—pneumatic**

AIR TRAFFIC CONTROL EQUIPMENT
★ *Circle No.* 385
Air Trainers Link
Amplivox
Aveley Electric
Decca Radar
Ekco Electronics
Electro-Mechanical Systems
Epsylon Industries
Gresham Developments
Marconi, W. T.
Rank Cintel
Thermionic Products

AMPLIDYNES. See **Amplifiers, rotating electric**

AMPLIFIERS, electronic analogue computing
★ *Circle No.* 386
A.E.I.
Airmec
Air Trainers Link
Aveley Electric
Blackburn Electronics
Bruce Peebles
Electronic Associates
Elliott Nucleonics
EMI Electronics
Epsylon Industries
Ericsson Telephones
Evershed & Vignoles
Feedback
Fleming Radio
Gresham Developments
Lancashire Dynamo Elect.
Louis Newmark
Miles-Hivolt
Mullard Equipment
Nash & Thompson
Newman Industries
Panellit
Peto Scott
Saunders Roe
S.E. Laboratories
Servomex Controls
Short Bros. & Harland
Teledictor
Thermionic Products
White & Riches
Winston Electronics

AMPLIFIERS, electronic and magnetic servo—a.c. to a.c.
★ *Circle No.* 387
A.E.I.
A.C.M. Electronics
Aero Transformers
Airtech
Armstrong Whitworth Equip.
Automation Consultants
Automa Engineering
Aveley Electric
Brown, S. G.
Bruce Peebles
Brush Electrical
Bryan Savage
C.J.R.
Cossor Instruments
Craven Electronics
Davy & United Instruments
De Havilland Propellers
Dynatron Radio
EMI Electronics
Ericsson Telephones
Evershed & Vignoles
Farnell Instruments
Ferranti
Films & Equipments
George Kent
Goodmans Industries
Gresham Developments
Gresham Transformers
Haddon Transformers
Hartley Electromotives
Harvey Electronics
Hirst Electronics
Honeywell Controls
James Scott Elec. Eng.
John Thompson Instrument
Ketay
Lancashire Dynamo Elect.
Laurence Scott
Louis Newmark
Mullard Equipment
Magneta Time Co
Mervyn Instruments
Miles-Hivolt
Muirhead
N.S.R. Manufacturing
Parmeko
Plessey Co.
Pullin, R. B.
Research & Control Inst.
Sanders (Electronics), W. H.
Solartron
Sperry Gyroscope
S.S. Electronics
Teledictor
Tinsley, H.
Venner Electronics
Welmec Corporation
Woden Transformer

AMPLIFIERS, electronic and magnetic servo—a.c. to d.c.
★ *Circle No.* 388
A.E.I.
Aero Transformers
Airtech
Armstrong Whitworth Equip.
Automa Engineering
Aveley Electric
Bruce Peebles
Brush Electrical
C.J.R.
Craven Electronics
Davy & United Instruments
De Havilland Propellers
Dobbie McInnes
Electro-Mechanical Systems
English Electric
Evershed & Vignoles
Farnell Instruments
Films & Equipments
George Kent
Graseby Instruments
Gresham Developments
Gresham Transformers
Haddon Transformers
Harvey Electronics
Hirst Electronics
Kelvin & Hughes
Ketay
Lancashire Dynamo Elec.
Lancashire Dynamo Nevelin
Laurence Scott
Louis Newmark
Magneta Time Co.
N.S.R. Manufacturing
Parmeko
Plessey Company
Research & Control Inst.
Sanders (Electronics), W. H.
S.E. Laboratories
Sperry Gyroscope
S.S. Electronics
Welmec Corporation
Woden Transformer

AMPLIFIERS, electronic and magnetic servo—d.c. to d.c.
★ *Circle No.* 389
Aero Transformers
A.E.I.
Airtech
Armstrong Whitworth Equip.
Automa Engineering
Automation Consultants
Aveley Electric
Blackburn Electronics
Brookhirst Igranic
Bruce Peebles
Brush Electrical
C.J.R.
Correx
Craven Electronics
De Havilland Propellers
Elliott Nucleonics
Evershed & Vignoles
George Kent
Gresham Developments
Gresham Transformers
Haddon Transformers
Hobson, H. M.
Honeywell Controls
Kendall & Mousley
Lancashire Dynamo Elect.
Laurence Scott
Louis Newmark
Magneta Time Co.
Parmeko
Plessey Co.
Research & Control Inst.
Sanders (Electronics), W. H.
S.E. Laboratories
S.S. Electronics
Swartwout
Welmec Corporation
Woden Transformer

AMPLIFIERS, electronic and magnetic servo—d.c. to d.c.
★ *Circle No.* 390
A.E.I.
Aero Transformers
Airmec
Airtech
Air Trainers Link
Allied Electronics
Armstrong Whitworth Equip.
Automa Engineering
Automation Consultants
Aveley Electric
Bailey Meters & Control
Brookhirst Igranic
Bruce Peebles
Brush Electrical
C.J.R.
Correx

★ *For further details circle on card facing page 214*

Cossor Instruments
Craven Electronics
De Havilland Propellers
Evershed & Vignoles
Electro-Mechanical Systems
Electro Methods
Elliott Brothers
Feedback
Fielden Electronics
Gallenkamp, A.
George Kent
Gresham Developments
Gresham Transformers
Haddon Transformers
Hartley Electromotives
Harvey Electronics
Hatfield Instruments
Hilger & Watts
Hobson, H. M.
James Scott Elect. Eng.
Kelvin & Hughes
Lancashire Dynamo Elect.
Laurence Scott
Lintronic
Louis Newmark
Magneta Time Co.
Miles-Hivolt
Mullard Equipment
Newman Industries
Parmeko
Pye, W. G.
Research & Control Inst.
Sanders (Electronics), W. H.
Sangamo Weston
Scientific Furnishings
S.E. Laboratories
Servomex Controls
Solartron
Southern Instruments
S.S. Electronics
Sunvic Controls
Tinsley, H.
Welmec Corporation

AMPLIFIERS, hydraulic servo
★ *Circle No.* 391

A.E.I.
Armstrong Whitworth Equip.
Baldwin Industrial Controls
Bell Precision
Dowty Equipment
Electroflo Meters
Electro-Hydraulics
Elliott Brothers
Hobson, H. M.
Integral
Isenthal
Keelavite Hydraulics
Maxam Power
Muirhead
Reavell-Fahie
S.E. Laboratories
Short Bros. & Harland
Welmec Corporation

AMPLIFIERS, mechanical servo
★ *Circle No.* 392

Air Trainers Link
Baldwin Industrial Controls
Bruce Peebles
Electro-Hydraulics
Graseby Instruments
Miles-Hivolt
Whites & Riches

AMPLIFIERS, pneumatic servo
★ *Circle No.* 393

Automa Engineering
Bailey Meters & Control
Baldwin Industrial Controls
Cheltenham Autocontrols
Electroflo Meters
Electro-Hydraulics
George Kent
James Gordon
Maxam Power
S.E. Laboratories
Sigma Inst.

AMPLIFIERS, rotating electric. See also **Ward Leonard sets**
★ *Circle No.* 394

Bruce Peebles
Brush Electrical
English Electric
Lancashire Dynamo Elect.
Laurence Scott
Mawdsley's
Sanders (Electronics), W. H.
Servo & Electronic Sales
Vernons Industries

ANALOGUE COMPUTERS. See Computers, analogue

ANALYTICAL INSTRUMENTS, continuous reading for gases —β-ray
★ *Circle No.* 395

Bellingham & Stanley
Elliott Brothers
Research & Control Inst.

ANALYTICAL INSTRUMENTS, continuous reading for gases —chemical absorption
★ *Circle No.* 396

Electroflo Meters
Evans Electroselenium
Glass Developments
James Gordon
Joyce Loebl
Kandem Electrical
Mervyn Instruments
Normalair
Southern Instruments

ANALYTICAL INSTRUMENTS, continuous reading for gases —chromatograph
★ *Circle No.* 397

Black Automatic Controls
Bruce Peebles
Elliott Brothers
Gallenkamp, A.
Griffin & George
Integra Leeds
Joyce Loebl
Perkin-Elmer
Pye, W. G.

ANALYTICAL INSTRUMENTS, continuous reading for gases —infra-red
★ *Circle No.* 398

Elliott Brothers
Gallenkamp, A.
Hilger & Watts
Infra Red Development
Joyce Loebl
Kandem Electrical
Mervyn Instruments
Mine Safety Appliances
Perkin-Elmer
Plessey Co.
Radiovisor Parent

ANALYTICAL INSTRUMENTS, continuous reading for gases —mass spectrometer
★ *Circle No.* 399

Bruce Peebles
Elliott Brothers
Farnell Instruments
Glass Developments
M.L. Aviation Company
20th. Century Electronics

ANALYTICAL INSTRUMENTS, continuous reading for gases —paramagnetic
★ *Circle No.* 400

Beckman Instruments
Cambridge Instruments
Farnell Instruments
Gallenkamp, A.
George Kent
Kandem Electrical
Research & Control Inst.
Servomex Controls

ANALYTICAL INSTRUMENTS, continuous reading for gases —polarograph
★ *Circle No.* 401

B. & K. Labs.
Cambridge Instrument
Evershed & Vignoles
Integra Leeds
Mervyn Instruments
Nash & Thompson
Southern Instruments

ANALYTICAL INSTRUMENTS, continuous reading for gases —refractometric
★ *Circle No.* 402

Bellingham & Stanley
Elliott Brothers
Hilger & Watts
Integra Leeds

ANALYTICAL INSTRUMENTS, continuous reading for gases —thermal conductivity
★ *Circle No.* 403

Cambridge Instrument
Elliott Brothers
Gallenkamp, A.
George Kent
Integra Leeds
James Gordon
Kandem Electrical
Kelvin & Hughes
Mine Safety Appliances

ANALYTICAL INSTRUMENTS, continuous reading for gases —ultrasonic
★ *Circle No.* 404

Elliott Brothers

ANALYTICAL INSTRUMENTS, continuous reading for gases —ultraviolet
★ *Circle No.* 405

Engelhard (Hanovia Lamps)
Gallenkamp, A.
Hilger & Watts
Reynolds & Branson

ANALYTICAL INSTRUMENTS, continuous reading for gases —X-ray
★ *Circle No.* 406

Hilger & Watts
Joyce Loebl
Research & Control Inst.
20th. Century Electronics

ANALYTICAL INSTRUMENTS, continuous reading for liquids —colorimetric chemical analyser
★ *Circle No.* 407

Evans Electroselenium
Gallenkamp, A.
Glass Developments
Hilger & Watts
Joyce Loebl
Southern Instruments

ANALYTICAL INSTRUMENTS, continuous reading for liquids —β-ray
★ *Circle No.* 408

Research & Control Inst.

ANALYTICAL INSTRUMENTS, continuous reading for liquids —infra-red
★ *Circle No.* 409

Hilger & Watts
Integral
Joyce Loebl
Marvyn Instruments
Perkin Elmer

ANALYTICAL INSTRUMENTS, continuous reading for liquids —polarimetric
★ *Circle No.* 410

Bellingham & Stanley
Cambridge Instrument
Ericsson Telephones
Hilger & Watts
Nash & Thompson

ANALYTICAL INSTRUMENTS, continuous reading for liquids —refractometric
★ *Circle No.* 411

Bellingham & Stanley
Elliott Brothers
Hilger & Watts

ANALYTICAL INSTRUMENTS, continuous reading for liquids —ultra-violet
★ *Circle No.* 412

Elliott Brothers
Hilger & Watts
Joyce Loebl

ANALYTICAL INSTRUMENTS, continuous reading for liquids —viscosity type
★ *Circle No.* 413

Elliott Brothers

ANALYTICAL INSTRUMENTS, continuous reading for liquids —X-ray
★ *Circle No.* 414

Hilger & Watts
Research & Control Inst.

ANALYTICAL INSTRUMENTS, continuous reading for liquids —nuclear magnetic resonance
★ *Circle No.* 415

Mullard Equipment
Research & Control Inst.

ANNUNCIATORS
★ *Circle No.* 416

Mimic Diagrams
Panellit
Thorn Electrical Industries

BALANCING MACHINES— dynamic
★ *Circle No.* 417

A.E.I.
Alfred Herbert
Allied Electronics
Birfield Industries
Brush Electrical
B.S.A. Tools Division
C.F.R. Giesler
Dawe Instruments
EMI Electronics
Farnell Instruments
Jackson & Bradwell
Small Electric Motors

BALANCING MACHINES— static
★ *Circle No.* 418

Birfield Industries
B.S.A. Tools Division
Giesler, C. F. R.
Jackson & Bradwell

BEARINGS, BALL—general
★ *Circle No.* 419

B.M.B. Sales
Fischer Bearings
High Precision Equipment
Hoffmann Mfg.
Ransome Marles Bearing
Stewart Aero Supply
Warden, A.

BEARINGS, BALL—miniature
★ *Circle No.* 420

B.M.B. Sales
E.M.O. Instrumentation
Fischer Bearings
Hoffmann Mfg.
Miniature Bearings
Stewart Aero Supply

BEARINGS, NEEDLE
★ *Circle No.* 421

INA Needle Bearings

BAROMETERS—aircraft
★ *Circle No.* 422

Bryans Aeroequipment
Firth Cleveland Instruments
Kelvin & Hughes
Mechanism Ltd.

BAROMETERS—mercury
★ *Circle No.* 423

Bryans Aeroequipment
Darton, F.
Griffin & George
Negretti & Zambra
Newbold & Bulford
Short & Mason
Stanley, W. F.

BAROMETERS—recording
★ *Circle No.* 424

Appleby & Ireland
Bristol Inst.
Darton, F.
Elliott Brothers
Firth Cleveland Instruments
Mechanism
Negretti & Zambra
Newbold & Bulford
Short & Mason
Stanley, W. F.

BATTERIES. See **Cells, electric**

BELLOWS—differential pressure
★ *Circle No.* 425

Appleby & Ireland
Bristol Inst.
Delta Technical Services
Drayton Regulator
Elliott Brothers
Payne & Griffiths
Teddington Ind. Equip.

BELLOWS—leather
★ *Circle No.* 426

George, Angus
Henry Beakbane
James W. Carr

BELLOWS—metallic
★ *Circle No.* 427

Appleby & Ireland
Avica Equipment
Drayton Regulator
Pioneer Designs
Teddington Refrigeration

BELLOWS—plastic
★ *Circle No.* 428

Henry Beakbane

BELLOWS—rubber
★ *Circle No.* 429

Delta Technical Services
Dunlop Rubber
George Angus
Griffin & George
Hall & Hall
Henry Beakbane
John Bull Rubber
Precision Rubbers
Ronald Trist

BELLOWS—thermostatic
★ *Circle No.* 430

Drayton Regulator
Perl Controls
Teddington Ind. Equip.

BLOWERS, instrument
★ *Circle No.* 431

Air Flow Developments
Air Pumps
Levis
Martindale Electric
Mortley Sprague
Parvalux
Reavell-Fahie
Volspray
Worthington Simpson

BOILER CONTROL SYSTEMS—industrial
★ *Circle No.* 432

Appleby & Ireland
Automation Systems
Bailey Meters & Control
Black Automatic Controls
Blackburn Electronics
Bristol Inst.
British Arca Regulators
British Sarozal
Cheltenham Autocontrols
Danfoss
Electroflo Meters
Electro-Mechanical Systems
Electrotechnic Ltd.
Elliott Brothers
Evershed & Vignoles
Fisher Governor
Foxboro-Yoxall
Fuel Efficiency
George Kent
Headland Eng. Developments
Honeywell Controls
Integra Leeds
James Gordon
John Thompson Instrument
Joseph Lucas (H. & C.)
Kandem Electrical
Kelvin & Hughes
Kingston Control Systems
Lancashire Dynamo Elect.
Lockheed Precision Products
Metropolitan Engineering
Newman Industries
Perl Controls
Photoelectronics (M.O.M.)
Radiovisor Parent
Rank Cintel
Reavell-Fahie
Rheostatic Co.
Ronald Trist
Sauter Controls
Smith & Sons England, S.
Teddington Ind. Equip.
Teleflex Products
Pye, W. G.

BOILER CONTROL SYSTEMS —marine
★ *Circle No.* 434

Bailey Meters & Control
Black Automatic Controls
Bristol Inst.
British Arca Regulators
Cheltenham Autocontrols
Electroflo Meters
Fisher Governor
Foxboro-Yoxall
Integra Leeds
James Gordon
John Thompson Instrument
Joseph Lucas (H. & C.)
Lockheed Precision Products
Photoelectronics (M.O.M.)
Pye, W. G.
Radiovisor Parent
Rank Cintel
Reavell-Fahie
Ronald Trist
Sunvic Controls
Teddington Ind. Equip.
Teleflex Products

BOILER CONTROL SYSTEMS —nuclear and power station
★ *Circle No.* 435

A.E.I.
Appleby & Ireland
Bailey Meters & Control
Black Automatic Controls
Blackburn Electronics
Bristol Inst.
British Arca Regulators
Brush Electrical
Electroflo Meters
Electrotechnic
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Fisher Governor
Foxboro-Yoxall
George Kent
Honeywell Controls
Integra Leeds
James Gordon
John Thompson Instrument
Joseph Lucas (H. & C.)
Kandem Electrical
Lockheed Precision Products
Metropolitan Engineering
Pye, W. G.
Radiovisor Parent
Ronald Trist
Sunvic Controls
Teddington Ind. Equip.
Teleflex Products

BOURDON—bellows
★ *Circle No.* 436

Appleby & Ireland
Bristol Inst.
Delta Technical Services
Drayton Regulator
Elliott Brothers
Payne & Griffiths

BOURDON—tubes
★ *Circle No.* 437

Appleby & Ireland
Bailey & Mackey
Bristol Inst.
Delta Technical Services
Elliott Brothers
Johnson Matthey
K.D.G. Instruments
Mechanism Ltd.
Payne & Griffiths
Sydney Smith

BRAKES—electromechanical
★ *Circle No.* 438

A.E.I.
B. & F. Carter
Brookhirst Igranic
Dewhurst & Partner
Mawdsley's
M.T.E. Control Gear
Plessey Co.
Simmons Electrical Winding

BRAKES—hydraulic
★ *Circle No.* 439

A.E.I.
Brookhirst Igranic
Dewhurst & Partner
Electro-Hydraulics
Lockheed Precision Products

BRAKES—magnetic
★ *Circle No.* 440

Autronic Developments
Brockhirst Igranic
Crofts
Dewhurst & Partner
G.E.C.
Morecambe Electrical
Oliver Pell
Permag Equipment
Rapid Magnetic Machines
Simmons Electrical Winding
Williams (B'ham), R. A.

BRAKES—pneumatic
★ *Circle No.* 441

B. & F. Carter
Crofts
Electro-Hydraulics
Westinghouse Brake

BRIDGES—a.c.
★ *Circle No.* 442

Aveley Electric
Bristol Inst.
British Central Elec.
British Physical Labs.
British Sarozal
Cambridge Instrument
Cossor Instruments
Cole (Overseas), R. H.
Claude Lyons
Elliott Brothers
Farnell Instruments
George Kent
Honeywell Controls
Kandem Electrical
Kelvin & Hughes
Marconi Instruments
Metrix Instruments
Muirhead

★ For further details circle on card facing page 214

Rank Cintel
S.E. Laboratories
Tinsley, H.
Wayne Kerr Labs.

BRIDGES—capacitance
★ *Circle No. 443*
Allied Electronics
Armstrong Whitworth Equip.
Aveley Electric
Avo
British Central Elec.
British Physical Labs.
Cambridge Instrument
Claude Lyons
Cole (Overseas), R. H.
Cossor Instruments
Farnell Instruments
Fielden Electronics
Firth Cleveland Instruments
Kandem Electrical
Leland Instruments
Marconi Instruments
Metrix Instruments
Muirhead
Nash & Thompson
Rank Cintel
Robinson & Partners, F. C.
Taylor Electrical
Telecommunication Inst.
Tinsley, H.
Wayne Kerr Labs.

BRIDGES—conductivity
★ *Circle No. 444*
A. M. Lock
Aveley Electric
British Central Elec.
Cambridge Instrument
Doran Instrument
Electronic Switchgear
Farnell Instruments
George Kent
Honeywell Controls
Kandem Electrical
Mullard Equipment
Pye, W. G.
Research & Control Inst.
Tinsley, H.
Wayne Kerr Labs.

BRIDGES—d.c.
★ *Circle No. 445*
Aveley Electric
Bristol Inst.
British Central Elec.
British Physical Labs.
British Sarozal
Cambridge Instrument
Claude Lyons
Cole (Overseas), R. H.
Croydon Precision Inst.
Doran Instrument
Elliott Brothers
Farnell Instruments
Gambrell Bros.
George Kent
Honeywell Controls
Marconi Instruments
Metrix Instruments
Muirhead
Pye, W. G.
Rank Cintel
Tinsley, H.
White Electrical Inst.

BRIDGES—impedance
★ *Circle No. 446*
Aveley Electric
British Central Elec.
British Physical Labs.
Claude Lyons
Cole (Overseas), R. H.
Farnell Instruments
Marconi Instruments
Metrix Instruments
Muirhead
Tinsley, H.
Wayne Kerr Labs.

BRIDGES—inductance
★ *Circle No. 447*
Allied Electronics
Aveley Electric
Avo
British Central Elec.
British Physical Labs.
Cambridge Instrument
Claude Lyons
Cole (Overseas), R. H.
Cossor Instruments
Farnell Instruments
Fielden Electronics
Furzehill Labs.
Marconi Instruments
Metrix Instruments
Muirhead
Nash & Thompson
Rank Cintel
Telecommunication Inst.
Tinsley, H.
Wayne Kerr Labs.

BRIDGES—power factor
★ *Circle No. 448*
Aveley Electric
British Central Elec.
Cambridge Instrument
Cole (Overseas), R. H.
Farnell Instruments
Muirhead
Miles-Hivolt
Telecommunication Inst.
Wayne Kerr Labs.

BRIDGES—resistance
★ *Circle No. 449*
Allied Electronics
Anders Electronics
Aveley Electric
Avo
Baldwin Industrial Controls
Bristol Inst.
British Central Elec.
British Physical Labs.
British Sarozal
Cambridge Instrument
Claude Lyons
Cole (Overseas), R. H.
Cossor Instruments
Croydon Precision Instruments
Doran Instrument
Elliott Brothers
Ericsson Telephones
Evershed & Vignoles
Fielden Electronics
Gambrell Bros.
George Kent
Honeywell Controls
Kandem Electrical
Marconi Instruments
Metrix Instruments
Muirhead
Nash & Thompson
Pye, W. G.
Rank Cintel
Robinson & Partners, F. C.
Taylor Electrical
Tinsley, H.
Wayne Kerr Labs.
White Electrical Inst.

BRIDGES—self-balancing
★ *Circle No. 450*
Benson-Lehner (G.B.)
British Central Elec.
Cambridge Instrument
Electronic Switchgear
Ericsson Telephones
Evershed & Vignoles
Firth Cleveland Instruments
George Kent
Honeywell Controls
Telecommunication Inst.
Wayne Kerr Labs.

BRIDGES—Schering
★ *Circle No. 451*
Aveley Electric
British Central Elec.
British Physical Labs.
Cole (Overseas), R. H.
Gambrell Bros.
Kandem Electrical
Marconi Instruments
Miles-Hivolt
Muirhead
Tinsley, H.

BRIDGES—strain gauge
★ *Circle No. 452*
Airtech
Boulton Paul Aircraft
British Central Elec.
Bryans Aeroequipment
Croydon Precision Instruments
Digital Engineering
Ericsson Telephones
Farnell Instruments
Honeywell Controls
Kelvin & Hughes
Lintronic
New Electronic Products
Pye, W. G.
Research & Control Inst.
Savage & Parsons
S. E. Laboratories
Southern Instruments
Tinsley, H.

BRIDGES—universal
★ *Circle No. 453*
Aerocontacts
Allied Electronics
Avo
British Central Elec.
British Physical Labs.
British Sarozal
Cambridge Instrument
Claude Lyons
Farnell Instruments
Holiday & Hemmerdinger
Kandem Electrical
Kelvin & Hughes
Marconi Instruments
Metrix Instruments
Muirhead
Taylor Electrical
Tinsley, H.
Wayne Kerr Labs.

BRIDGES—valve
★ *Circle No. 454*
British Central Elec.
Claude Lyons
Metrix Instruments
Taylor Electrical

BRIDGES—wattmeter
★ *Circle No. 455*
Aveley Electric
British Central Elec.
Decca Radar
K.G.M. Electronics
Telecommunication Inst.

BRIX INSTRUMENTS
★ *Circle No. 456*
Bellingham & Stanley
British Arca Regulators
Elliott Brothers
George Kent
Griffin & George
Honeywell Controls
Rotameter Mnfg.

BULK ERASERS
★ *Circle No. 457*
Ampex
Harvey Electronics

CABINETS
★ *Circle No. 458*
A.C.M. Electronics
Air Trainers Link
Alfred Imhof
Astral Switchgear
Bristol Inst.
British Sarozal
Bruce Peebles
C. & N. Electrical
Datum Metal Products
Electroflo Meters
Elliott Brothers
Hallam Sleigh & Cheston
Instrument Installations
Integra Leeds
John Thompson Instrument
Keelavite Hydraulics
Lintronic
Lund Bros.
Pelaphone Engines
Plessey Co.
Reosound Engineering
South London Elec. Equip.
Telecommunication Inst.
Tiltman Langley

CALLING SYSTEMS
★ *Circle No. 459*
A.E.I.
Autophone
Bryan Savage
Electromation
I.E.C.-Sieger
K.G.M. Electronics
Magneta Time Co.
Marconi I. M. Com.
Multitone Electric
Page Engineering
Reosound Engineering
Siemens Edison Swan
Sound Diffusion
S. S. Electronics
Standard Telephones

CAMERAS—high-speed
★ *Circle No. 460*
Benson-Lehner (G.B.)
Farnell Instruments
Kodak
Langham Thompson, J.
Peto Scott
Sealey Engineering

CAMERAS—oscilloscope recording
★ *Circle No. 461*
Armstrong Whitworth Equip.
Cossor Instruments
Farnell Instruments
Films & Equipments
Langham Thompson, J.
Leland Instruments
Peto Scott
Rank Cintel
Research & Control Inst.
Shackman, D.
Southern Instruments

CAPACITORS
★ *Circle No. 462*
Aveley Electric
B.I.C.C.
British Sarozal
Bulgin, A. F.
Cole (Overseas), R. H.
Erie Resistor
Farnell Instruments
Fuller Electric
G.E.C.
Holiday & Hemmerdinger
Jackson Bros.
Johnson & Phillips
Johnson Matthey
Kendall & Mousley
Leland Instruments
Muirhead
Mullard
Mycalex
Plessey Co.
Radiospares
Standard Telephones
Stewart Aero Supply
Telephone Mnfg.

CATHODE-RAY TUBES
★ *Circle No. 463*
Cathodeon
Cossor Instruments
EMI Electronics
Farnell Instruments
Ferranti
G.E.C.
Holiday and Hemmerdinger
Lee Products
Leland Instruments
Mullard
Rank Cintel
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones
20th. Century Electronics

CELLS, ELECTRIC—dry
★ *Circle No. 464*
British Central Elec.
G.E.C.
Griffin & George
Le Carbone (Great Britain)
Mallory Batteries
R.C.A. (G.B.)
Stewart Aero Supply
Varley Dry Accumulators
Vidor Batteries

CELLS, ELECTRIC—fuel
★ *Circle No. 465*
Marshall of Cambridge

CELLS, ELECTRIC—miniature
★ *Circle No. 466*
British Central Elec.
Mallory Batteries
Siemens Edison Swan
Stanley Palmer, G. A.
Vidor Batteries
Varley Dry Accumulators
Venner Accumulators

CELLS, ELECTRIC—mercury
★ *Circle No. 467*
Mallory Batteries
R.C.A. (G.B.)
Vidor Batteries

CELLS, ELECTRIC—standard
★ *Circle No. 468*
British Central Elec.
Cambridge Instrument
Crompton Parkinson
Croydon Precision Instruments
Gambrell Bros.
Le Carbone (Great Britain)
Muirhead
Pye, W. G.
Sangamo Weston
Smith & Sons (England), S.
Tinsley, H.
Varley Dry Accumulators
Vidor Batteries
White Electrical Inst.

CELLS, ELECTRIC—storage
★ *Circle No. 469*
Birfield Industries
British Central Elec.
Crompton Parkinson
D.P. Battery
Griffin & George
Mine Safety Appliances
Nife Batteries
Radenite Batteries
Stanley Palmer, G. A.
Stewart Aero Supply
Varley Dry Accumulators
Venner Accumulators

CELLS, LOAD. See **Load cells**

CHOPPER RELAYS. See **Relays, electric-chopper**

CLOCKS—aircraft
★ *Circle No. 470*
Aerocontacts
Devon Instruments
Miles-Hivolt
Stewart Aero Supply

CLOCKS—astronomical
★ *Circle No. 471*
Aveley Electric
Magneta Time Co.

CLOCKS—laboratory
★ *Circle No. 472*
Automatic Telephone
Aveley Electric
British Central Elec.
Devon Instruments
Electric Remote Control
Glass Developments
Grasbey Instruments
Lancashire Dynamo Elect.
Landis & Gyr
Magneta Time Co.
Pye, W. G.
Thermionic Products
Venner Electronics

CLOCKS—marine
★ *Circle No. 473*
Devon Instruments
Dobbie McInnes
Landis & Gyr
Siemens Edison Swan
Smith & Sons (England), S.
Stanley & Co., W. F.
Smiths Industrial Inst.
Sperry Gyroscope
Thomas Mercer

CLUTCHES—electromechanical
★ *Circle No. 474*
Austinlite
Autronic Developments
Air Trainers Link
Brookhirst Igranic
G.E.C.
Grasby Instruments
Mawdsley's
Miles-Hivolt
Oliver Pell
Simmons Electrical Winding
Tiltman Langley
Westool

CLUTCHES—fluid
★ *Circle No. 475*
Crofts
Electro-Mechanical Systems
Miles-Hivolt
S. E. Laboratories

CLUTCHES—magnetic particle
★ *Circle No. 476*
Crofts
Miles-Hivolt
Oliver Pell
Smith & Sons (England), S.
Welmec Corporation

CLUTCHES—mechanical
★ *Circle No. 477*
Alfred Herbert
Birfield Industries
Carter, B. & F.
Crofts
Lockheed Precision Products
Miles-Hivolt
Plessey Company
Renold Chains
Tiltman Langley

COLORIMETERS, continuous reading. See under **Photometric instruments**

COMBINATION LOGIC EQUIPMENT
★ *Circle No. 478*
Brookhirst Igranic
Bruce Peebles
Ericsson Telephones
Gresham Developments
Lancashire Dynamo Elect.
Miles-Hivolt
Mullard Equipment
Plessey Co.
Sanders (Electronics), W. H.
Woden Transformer

COMBUSTION CONTROL
See **Boiler control systems**

COMPARATORS, COLOUR. See under **Photometric instruments**

COMPARATORS—electrical
★ *Circle No. 479*
Alfred Herbert
Allied Electronics
Aveley Electric
British Central Elec.
British Physical Labs.
Croydon Precision Instruments
Sigma Inst.
Taylor, Taylor & Hobson
Vernon Instrument

COMPARATORS—electronic
★ *Circle No. 480*
Automatic Telephone
Aveley Electric
Blackburn Electronics
British Central Elec.
British Physical Labs.
Craven Electronics
Electronic Associates
James Scott Elec. Eng.
Lancashire Dynamo Elect.
Leland Instruments
Lintronic
Plessey Co.
Saunders-Roe
Southern Instruments
Teledictor
Vernon Instrument

COMPARATORS—impedance
★ *Circle No. 481*
Aveley Electric
British Central Elec.
British Physical Labs.
Claude Lyons
Cole (Overseas), R. H.
Dawe Instruments
Wayne Kerr Labs.

COMPARATORS—mechanical
★ *Circle No. 482*
Alfred Herbert
Baty, J. E.
Cambridge Instrument
James W. Carr
Plessey Co.
Sigma Inst.
Thomas Mercer
Vernon Instrument

COMPUTERS, air data
★ *Circle No. 483*
Elliott Brothers
Gresham Developments
Kelvin & Hughes
Louis Newmark
Marconi, W. T.

COMPUTERS, electromechanical analogue
★ *Circle No. 484*
Aveley Electric
Air Trainers Link
Evershed & Vignoles
Elliott Brothers
Gresham Developments
Integral
Robinson & Partners, F. C.
Servo & Electronic Sales
Teledictor
White & Riches

COMPUTERS, electronic analogue—general purpose
★ *Circle No. 485*
A.E.I.
Airmec
Air Trainers Link
Armstrong Whitworth Equip.
Bruce Peebles
Electronic Associates
Elliott Brothers
Elliott Nucleonics
EMI Electronics
English Electric
Evershed & Vignoles
Fairey
Gresham Developments
Joyce Loebel
Laurence Scott
Louis Newmark
Miles-Hivolt
Nash & Thompson
Panellit
Robinson & Partners, F. C.
Royston Instruments
Saunders-Roe
Short Bros. & Harland

Solartron
Winston Electronics

COMPUTERS, electronic analogue—special purpose ★ *Circle No.* 486
A.E.I.
Air Trainers Link
Armstrong Whitworth Equip.
Blackburn Electronics
Bruce Peebles
Brush Electrical
De Havilland Propellers
Digital Engineering
Electronic Associates
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Fairey
Feedback
Gresham Developments
Integral
Joyce Loebl
Louis Newmark
Miles-Hivolt
Nash & Thompson
Newman Industries
Panellit
Plessey Co.
Saunders-Roe
Servomex Controls
Short Bros. & Harland
Solartron
Sunvic Controls
Teledictor
White & Riches
Winston Electronics

COMPUTERS, electronic digital—differential analyser ★ *Circle No.* 487
Armstrong Whitworth Equip.
Elliott Brothers
Gresham Developments

COMPUTERS, electronic digital—general purpose ★ *Circle No.* 488
A.E.I.
Brush Electrical
Burroughs
Elliott Brothers
EMI Electronics
English Electric
Ferranti
IBM United Kingdom
I.C.T.
Leo Computers
Panellit
R.C.A. (G.B.)
Royston Instruments
Standard Telephones

COMPUTERS, electronic digital—special purpose ★ *Circle No.* 489
De Havilland Propellers
Elliott Brothers
Epsylon Industries
Ferranti
Gresham Developments
Leo Computers
Lintronic
Nash & Thompson
Newman Industries
Panellit

COMPUTERS, mechanical analogue ★ *Circle No.* 490
Air Trainers Link
Elliott Brothers
Gresham Developments
Laurence Scott
Servo & Electronic Sales

CONTROLLERS. For general purpose controllers see under method of operation (i.e. **Controllers, electric, pneumatic** or **hydraulic**). For single-purpose controllers see under the physical quantity concerned (e.g. **Temperature controllers**).

CONTROLLERS, automatic ratio—electric inputs ★ *Circle No.* 491
Bristol Inst.
British Arca Regulators
Crater Products
Craven Electronics
De Havilland Propellers
Electroflo Meters
Elliott Brothers
Evershed & Vignoles
Hobson, H. M.
Honeywell Controls
Integra Leeds
John Thompson Instrument
Laurence Scott
Lancashire Dynamo Elect.
Lindars Automation
Plessey Co.
Reavell-Fahie
Research & Control Inst.
Swartwout
Taylor Controls
Timothy Eaton
Watford Electric
Welmec Corporation

CONTROLLERS, automatic ratio—pneumatic inputs ★ *Circle No.* 492
Appleby & Ireland
Bailey Meters & Control
Bristol Inst.
British Arca Regulators
Cheltenham Autocontrols
Electroflo Meters
Elliott Brothers
Foxboro-Yoxall
George Kent
Hobson, H. M.
Honeywell Controls
Integra Leeds
James Gordon
Reavell-Fahie
Sunvic Controls
Taylor Controls
Timothy Eaton

CONTROLLERS, electrical—floating ★ *Circle No.* 493
A. M. Lock
Automation Systems
British Arca Regulators
Electroflo Meters
Foster Instrument
Fuel Efficiency
Gresham Developments
Headland Eng. Developments
Honeywell Controls
Isenthal
James Gordon
Lancashire Dynamo Elect.
Laurence Scott
Rheostatic Co.
Sauter Controls
Teddington Ind. Equip.
Telemeters

CONTROLLERS, electrical—proportional ★ *Circle No.* 494
Bailey Meters & Control
Bristol Inst.
British Arca Regulators
C.N.S. Instruments
Dewrance
Drayton Regulators
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Ether
Foster Instrument
Fuel Efficiency
Gresham Developments
Headland Eng. Developments
Honeywell Controls
Integra Leeds
Isenthal
James Gordon
Kelvin & Hughes
Lancashire Dynamo Elect.
Laurence Scott
Rheostatic Co.
Sanders (Electronics), W. H.
Sauter Controls
Sifam Electrical Instrument
South London Elec. Equip.
Swartwout
Taylor Controls
Teddington Ind. Equip.
Telemeters
Vidor Batteries
Welmec Corporation

CONTROLLERS, electrical—proportional-integral ★ *Circle No.* 495
Bailey Meters and Control
Bristol Inst.
British Arca Regulators
Dewrance
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Foster Instrument
Fuel Efficiency
Gresham Developments
Headland Eng. Developments
Honeywell Controls
Integra Leeds
James Gordon
Lancashire Dynamo Elect.
Laurence Scott
Rheostatic Co.
South London Elec. Equip.
Sperry Gyroscope
Swartwout
Taylor Controls
Teddington Ind. Equip.
Welmec Corporation

CONTROLLERS, electrical—proportional-integral-derivative ★ *Circle No.* 496
Bailey Meters & Control
Bristol Inst.
British Arca Regulators
Dewrance
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Foster Instrument
Gresham Developments
Honeywell Controls
Integra Leeds
James Gordon
Laurence Scott
Kandem Electrical
Lancashire Dynamo Elect.
Research & Control Inst.
Swartwout
Taylor Controls
Teddington Ind. Equip.
Welmec Corporation

CONTROLLERS, electrical—two position (e.g. on-off) ★ *Circle No.* 497
Addison Electric
Automation Systems
Bailey Meters & Control
Bristol Inst.
British Arca Regulators
British Central Elec.
Coley Thermometers
Cambridge Instrument
Crater Products
Drayton Regulator
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Ericsson Telephones
Ether
Firth Cleveland Instruments
Foster Instrument
Foxboro-Yoxall
Fuel Efficiency
George Kent
Gresham Developments
Headland Eng. Developments
Honeywell Controls
Industrial Pyrometer
Integra Leeds
James Gordon
John Thompson Instrument
Kandem Electrical
K.D.G. Instruments
Kelvin & Hughes
Lancashire Dynamo Elect.
Laurence Scott
Metrix Instruments
Negretti & Zambra
Plessey Company
Pye, W. G.
Research and Control Inst.
Rheostatic Co.
Robinson, D.
Sanders (Electronics), W. H.
Sauter Controls
Sifam Electrical Instrument
South London Elec. Equip.
Teddington Ind. Equip.
Telemeters
Vidor Batteries
Venner Electronics
Welmec Corporation

CONTROLLERS, hydraulic—floating ★ *Circle No.* 498
British Arca Regulators
Electro-Hydraulics
Electroflo Meters
Lockheed Precision Products
Oswalds & Ridgway
Reavell-Fahie
Spirax-Sarco

CONTROLLERS, hydraulic—proportional ★ *Circle No.* 499
Bell Precision
British Arca Regulators
Dowty Equipment
Electroflo Meters
Evershed & Vignoles
Electro-Hydraulics
H.M.L.
Integral
Lockheed Precision Products
P.A.R.
Reavell-Fahie

CONTROLLERS, hydraulic—proportional-integral ★ *Circle No.* 500
British Arca Regulators
Dowty Equipment
Electroflo Meters
Evershed & Vignoles
Electro-Hydraulics
H.M.L.
Lockheed Precision Products
Reavell-Fahie

CONTROLLERS, hydraulic—proportional-integral-derivative ★ *Circle No.* 501
British Arca Regulators
Dowty Equipment
Electroflo Meters
Electro-Hydraulics
H.M.L.
Lockheed Precision Products
Reavell-Fahie

CONTROLLERS, hydraulic—two position (e.g. on-off) ★ *Circle No.* 502
Birfield Industries
British Arca Regulators
Dowty Equipment
Dowty Hydraulic Units
Electro-Hydraulics
High Pressure Components
H.M.L.
Integral
Lockheed Precision Products
Oswalds & Ridgway
Reavell-Fahie
Spirax-Sarco

CONTROLLERS, pneumatic—floating ★ *Circle No.* 503
Automation Systems
British Arca Regulators
Electroflo Meters
Electro-Hydraulics
Foxboro-Yoxall
Honeywell Controls
James Gordon
Sunvic Controls
T. A. L. Numatics
Taylor Controls

CONTROLLERS, pneumatic—proportional ★ *Circle No.* 504
British Arca Regulators
Bristol Inst.
Bailey Meters & Control
Cambridge Instrument
Crosby Valve & Eng.
Drayton Regulator
Elliott Brothers
Elliott Nucleonics
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Fisher Governor
Foxboro-Yoxall
George Kent
Honeywell Controls
Integra Leeds
James Gordon
Negretti & Zambra
Samson Controls
Sunvic Controls
Sauter Controls
T. A. L. Numatics
Taylor Controls
Westinghouse Brake

CONTROLLERS, pneumatic—proportional-integral ★ *Circle No.* 505
Bristol Inst.
British Arca Regulators
Bailey Meters & Control
Cheltenham Autocontrols
Crosby Valve & Eng.
Drayton Regulator
Electroflo Meters
Electro-Hydraulics
Elliott Brothers
Elliott Nucleonics
Fisher Governor
Foxboro-Yoxall
George Kent
Honeywell Controls
Integra Leeds
James Gordon
Negretti & Zambra
Samson Controls
Sunvic Controls
Sauter Controls
Taylor Controls
Westinghouse Brake

CONTROLLERS, pneumatic—proportional-integral-derivative ★ *Circle No.* 506
Bristol Inst.
British Arca Regulators
Bailey Meters & Control
Cheltenham Autocontrols
Electroflo Meters
Electro-Hydraulics
Elliott Brothers
Elliott Nucleonics
Foxboro-Yoxall
George Kent
Honeywell Controls
Integra Leeds
James Gordon
Negretti & Zambra
Sigma. Inst.
Sunvic Controls
Sauter Controls
Taylor Controls

CONTROLLERS, pneumatic—two position (e.g. on-off) ★ *Circle No.* 507
Air Automation
Bailey Meters & Control
Birfield Industries
British Arca Regulators
Crosby Valve & Eng.
Drayton Regulator
Electroflo Meters
Electro-Hydraulics
Elliott Brothers
Elliott Nucleonics
Fisher Governor
Foxboro-Yoxall
Honeywell Controls
High Pressure Components
Integra Leeds
James Gordon
Sauter Controls
Sunvic Controls
T. A. L. Numatics
Taylor Controls
Westinghouse Brake

CONTROLLERS, programme—electrical output ★ *Circle No.* 508
Automation Systems
A.E.I.
Aveley Electric
Bristol Inst.
British Sarozal
Burrell, A. B.
Bruce Peebles
British Federal Welder
Cambridge Instrument
Craven Electronics
De Havilland Propellers
Digital Engineering
Elcontrol
Electric Remote Control
Electroflo Meters
Elliott Brothers
Ericsson Telephones
Ether
Foster Instrument
Gresham Developments
George Kent
Honeywell Controls
Integra Leeds
Lancashire Dynamo Elect.
Lindars Automation
Magneta Time Co.
Nickols Automatics
Radiatron
Research & Control Inst.
Robinson, D.
Royston Instruments
Shackman, D.
South London Elec. Equip.
Sutton Coldfield Elec. Eng.
Sauter Controls
Thomas Walker
Tully Engineering
Venner Electronics

CONTROLLERS, programme—pneumatic output ★ *Circle No.* 509
A.E.I.
Automation Systems
Bristol Inst.
Burrell, A. G.
Cambridge Instrument
Cheltenham Autocontrols
Drayton Regulator
Electroflo Meters
Elliott Brothers
Fisher Governor
Foxboro-Yoxall
George Kent
Honeywell Controls
James Gordon
Nickols Automatics
Sauter Controls
Sutton Coldfield Elec. Eng.
Taylor Controls
Thomas Walker

COUPLINGS, PIPE—quick-release ★ *Circle No.* 510
Airtech
Albert Mann Eng.
Alfred Bullows
A. Schrader's Son
Avery Hardoll
Avimo
Drallim Industries
Dunlop Rubber
Dowty Hydraulics Units
Feeny & Johnson
Flight Refuelling
Guyson Industrial Equip.
High Pressure Components
H.M.L.
Joseph Lucas (H. & C.)
Lockheed Precision Products
Thos. Ryder
Volspray

COUPLINGS, PIPE—self-sealing ★ *Circle No.* 511
Armstrong Whitworth Equip
A. Schrader's Son
Avery Hardoll
Avimo
Dowty Hydraulic Units
Dunlop Rubber
Exactor
Flight Refuelling
Guyson Industrial Equip.
High Pressure Components
H.M.L.
Joseph Lucas (H. & C.)
Lockheed Precision Products
N.G.N. Electrical
Thos. Ryder

COUPLINGS, SHAFT—flexible ★ *Circle No.* 512
Air Trainers Link
Birfield Industries
Crofts
Icknield Engineering
Jackson Bros.
James W. Carr
Pioneer Designs
Renold Chains
Servomex Controls
Smith & Sons (England), S.
Standage Power Couplings
Warden & Co., A.
White Dental Mfg.

COUPLINGS, SHAFT—miniature ★ *Circle No.* 513
Bulgin, A. F.
Drayton Regulator
Icknield Engineering
Jackson Bros.
Pioneer Designs

COUNTERS—batch ★ *Circle No.* 514
A.E.I.
Airmec
Airtech
Ariel Sound
Atkins Robertson
Automa Engineering
Automation Consultants
B. & F. Carter
British Federal Welder
Bruce Peebles
Counting Instruments
Craven Electronics
De Havilland Propellers
Digital Engineering
Elcontrol
Ericsson Telephones
Farnell Instruments
Firth Cleveland Instruments
H. & B. Precision Eng.
Hasler Telegraph Works
Icknield Engineering
K.G.M. Electronics
Lancashire Dynamo Elect.
Langham Thompson, J.
Lindars Automation
Lintronic
Londex
Mullard Equipment
Newman Industries

★ *For further details circle on card facing page 214*

Photoelectronics (M.O.M.)
Racal Instruments
Radiatron
Radiovisor Parent
Robinson & Partners, F. C.
Sargrove Electronics
Sciaky Electric Welding
Smiths Industrial Inst. Div.
Stonebridge Electrical
Sutton Coldfield Elec. Eng.
Telecommunication Inst.
Thomas Walker
Timothy Eaton
Tyer
Valley Products Lye
Veeder-Root
Venner Electronics
Welmec Corporation
Winston Electronics

COUNTERS—binary
★ *Circle No.* 515

Airmec
Airtech
Allied Electronics
Automation Consultants
Bruce Peebles
Counting Instruments
Craven Electronics
De Havilland Propellers
Digital Engineering
Dynatron Radio
Ericsson Telephones
Gresham Developments
Integral
Joyce Loebl
K.G.M. Electronics
Lancashire Dynamo Elect.
Lindars Automation
Lintronic
Newman Industries
Racal Instruments
Rank Cintel
Research & Control Inst.
Veeder-Root
Venner Electronics
Winston Electronics

COUNTERS—decade
★ *Circle No.* 516

Advance Components
Airmec
Airtech
Allied Electronics
Ariel Sound
Automation Consultants
British Federal Welder
Bruce Peebles
Carter, B. & F.
Craven Electronics
De Havilland Propellers
Digital Engineering
Dynatron Radio
Ekco Electronics
Elcontrol
Elliott Nucleonics
Ericsson Telephones
Erie Resistor
Farnell Instruments
Firth Cleveland Instruments
Fleming Radio
General Controls
H. & B. Precision Eng.
Hirst Electronic
Integral
K.G.M. Electronics
Labgear
Lancashire Dynamo Elect.
Langham Thompson, J.
Lintronic
Marconi Instruments
Mullard Equipment
Newman Industries
Panax Equipment
Photoelectronics (M.O.M.)
Racal Instruments
Radiovisor Parent
Rank Cintel
Research & Control Inst.
Sciaky Electric Welding
Stonebridge Electrical
Timothy Eaton
Vidor Batteries
Veeder-Root
Venner Electronics
Welmec Corporation
Winston Electronics

COUNTERS—geiger
★ *Circle No.* 517

Airmec
Aveley Electric
Dynatron Radio
Ekco Electronics
Ericsson Telephones
General Radiological
Isotope Developments
Labgear
Panax Equipment
Radiation Monitors
Rank Cintel
Research & Control Inst.
20th. Century Electronics
Vidor Batteries

COUNTERS—neutron
★ *Circle No.* 518

Plessey Nucleonics

COUNTERS—impulse
★ *Circle No.* 519

Advance Components
Aveley Electric
British Federal Welder
Bruce Peebles
Carter, B. & F.
Counting Instruments
Craven Electronics
Elcontrol
English Numbering Machine
Ericsson Telephones
Erie Resistor
Firth Cleveland Instru.
H. & B. Precision Eng.
Hasler Telegraph Works
Hirst Electronic
Inglis Knibb
Jack Davis Relays
K.G.M. Electronics
Labgear
Lancashire Dynamo Elect.
Langham Thompson, J.
Lintronic
Londex
Measurement Ltd.
Mullard Equipment
Racal Instruments
Radiatron
Radiovisor Parent
Rank Cintel
Research & Control Inst.
Sciaky Electric Welding
Smiths Industrial Inst.
Stonebridge Electrical
Thomas Walker
Timothy Eaton
Veeder-Root
Venner Electronics
Winston Electronics

COUNTERS—mechanical
★ *Circle No.* 520

Carter, B. & F.
Counting Instruments
Devon Instruments
English Numbering Machine
Firth Cleveland Instruments
General Controls
H. & B. Precision Eng.
Hasler Telegraph Works
Icknield Engineering
Kontak Manufacturing
Langham Thompson, J.
Radiatron
Robert Pringle & Sons
Smiths Industrial Inst.
Thomas Walker
Veeder-Root
Winston Electronics

COUNTERS—photocell
★ *Circle No.* 521

A.E.I.
Airmec
Allied Electronics
Ariel Sound
Atkins Robertson
Autema Engineering
Bruce Peebles
Counting Instruments
Craven Electronics
Digital Engineering
Elcontrol
Ericsson Telephones
Farnell Instruments
Firth Cleveland Instruments
General Electric
H. & B. Precision Eng.
Lancashire Dynamo Elect.
Lintronic
Londex
Mullard Equipment
Newman Industries
Photoelectronics (M.O.M.)
Radiovisor Parent
Sargrove Electronics
Sciaky Electric Welding
Stonebridge Electrical
Sutton Coldfield Elec. Eng.
Thomas Walker
Timothy Eaton
Tyer
Veeder-Root
Venner Electronics
Winston Electronics

COUNTERS—printing
★ *Circle No.* 522

Counting Instruments
Craven Electronics
English Numbering Machine
Ericsson Telephones
Labgear
Mullard Equipment
Radiatron
R.C.A. (G.B.)
Stonebridge Electrical
Veeder-Root
Winston Electronics

COUNTERS—revolution
★ *Circle No.* 523

Armstrong Whitworth Equip.
Atkins Robertson
Automation Consultants
Bruce Peebles
Carter, B. & F.
Counting Instruments
Craven Electronics
Devon Instruments
Ericsson Telephones
Erie Resistor
English Numbering Machine
Farnell Instruments
Firth Cleveland Instruments
General Controls
Hasler Telegraph Works
Icknield Engineering
Integral
James W. Carr
Labgear
Lancashire Dynamo Elect.
Langham Thompson, J.
Lintronic
Mullard Equipment
Racal Instruments
Radiatron
Rank-Cintel
Robert Pringle & Sons
Smith & Sons (England), S.
Smiths Industrial Inst.
Stonebridge Electrical
Thomas Walker
Veeder-Root
Venner Electronics
Winston Electronics

COUNTERS—scintillation
★ *Circle No.* 524

Airmec
Dynatron Radio
Ekco Electronics
Ericsson Telephones
General Radiological
Isotope Developments
Joyce Loebel
Labgear
Mervyn Instruments
Nuclear Enterprises
Panax Equipment
Plessey Nucleonics
Rank-Cintel
Research & Control Inst.
20th. Century Electronics
Vidor Batteries

CONVERTERS, data—analogue-digital
★ *Circle No.* 525

A.E.I.
Armstrong Whitworth Equip.
Benson-Lehner (G.B.)
B. & K. Labs.
Blackburn Electronics
Bruce Peebles
Bryans Aeroequipment
C.N.S. Instruments
Colvern
Davy & United Instruments
De Havilland Propellers
Digital Engineering
Dobbie McInnes
Electronic Associates
Elliott Brothers
Elliott Nucleonics
Epsylon Industries
Ericsson Telephones
Evershed & Vignoles
G.E.C.
General Controls
Gresham Developments
Hilger & Watts
Lindars Automation
Lintronic
Marconi, W. T.
Mullard Equipment
Nash & Thompson
Plessey Co.
Racal Instruments
Research & Control Inst
Royston Instruments
S.E. Laboratories
Solartron
Southern Instruments
Sunvic Controls
Swartwout
Venner Electronics
Welmec Corporation

CONVERTERS, data—card-tape
★ *Circle No.* 526

Ferranti
Gresham Developments
Lindars Automation
Marconi, W. T.
R.C.A. (G.B.)
Royston Instruments
Southern Instruments
Underwood

CONVERTERS, data—digital-analogue
★ *Circle No.* 527

Armstrong Whitworth Equip.
Benson-Lehner (G.B.)
B. & K. Labs
Bruce Peebles
De Havilland Propellers
Digital Engineering
Dobbie McInnes
Electronic Associates
Ericsson Telephones
Gresham Developments
Integral
Lancashire Dynamo Elect.
Lintronic
Marconi, W. T.
Newman Industries
Plessey Co.
Royston Instruments
S.E. Laboratories
Southern Instruments
Winston Electronics

CONVERTERS, data—tape-card
★ *Circle No.* 528

Ferranti
Gresham Developments
Marconi, W. T.
R.C.A. (G.B.)
Royston Instruments
Timothy Eaton

CONVERTERS, electrical—rotary a.c.-d.c.
★ *Circle No.* 529

A.E.I.
British Central Elec.
Bruce Peebles
English Electric
Films & Equipments
G.E.C.
Laurence Scott
Mawdsley's
Mortley Sprague
Newton Brothers (Derby)
Sanders (Electronics), W. H.
Small Electric Motors
Stewart Aero Supply
Vernons Industries
Whitetrade

CONVERTERS, electrical—rotary d.c.-a.c.
★ *Circle No.* 530

A.E.I.
British Central Elec.
Bruce Peebles
English Electric
Films & Equipments
Kelvin & Hughes
Laurence Scott
Magneta Time Co.
Mawdsley's
Mortley Sprague
Newton Brothers (Derby)
Plessey Co.
Sanders (Electronics), W. H.
Small Electric Motors
Stewart Aero Supply
Vernons Industries
Walter Jones
Whitetrade
Wilkinson (Croydon), L.

CONVERTERS, electrical—mercury arc
★ *Circle No.* 531

A.E.I.
Austinlite
British Central Elec.
Bruce Peebles
English Electric
G.E.C.
Hackbridge & Hewittic
Hirst Electronics
Lancashire Dynamo Nevelin
Miles-Hivolt

CONVERTERS, electrical—transistorized a.c.-d.c.
★ *Circle No.* 532

De Havilland Propellers
Sealey Engineering

CONVERTERS, electric-hydraulic
★ *Circle No.* 533

Appleby & Ireland
Dewrance
Electroflo Meters
Evershed & Vignoles
Integral
Reavell-Fahie
Woden Transformer

CONVERTERS, electric-pneumatic
★ *Circle No.* 534

Appleby & Ireland
British Arca Regulators
Bailey Meters & Control
Dewrance
Electroflo Meters
Evershed & Vignoles
Elliott Brothers
Elliott Nucleonics
Fisher Governor
Foxboro-Yoxall
Reavell-Fahie
Swartwout
Taylor Controls

CURRENT—limiters
★ *Circle No.* 535

British Central Elec.
Brookhirst Igranic
Bruce Peebles
Craven Electronics
Dewhurst & Partner
English Electric
Landis & Gyr
Sanders (Electronics), W. H.
Siemens-Schuckert
Stewart Aero Supply

CURRENT—regulators
★ *Circle No.* 536

A.E.I.
Allied Electronics
A.P.T. Electronic Industries
British Central Elec.
British Sarozal
Brookhirst Igranic
Bruce Peebles
Brush Electrical
Coventry Controls
Craven Electronics
English Electric
Hirst Electronics
John Morris Elec. Eng.
Kasama Electronics
Laurence Scott
Lancashire Dynamo Elect.
Newport Instruments
Sanders (Electronics), W. H.
Stewart Aero Supply

CURVE FOLLOWERS—automatic
★ *Circle No.* 537

Benson-Lehner (G.B.)
Cambridge Instruments
Craven Electronics
Electronic Associates
I.E.C.-Sieger
Lancashire Dynamo Elec.
Seeley Engineering
Southern Instruments
Telecommunication Inst.

CURVE FOLLOWERS—manual
★ *Circle No.* 538

Benson-Lehner (G.B.)
I.E.C.-Sieger

CYLINDERS, pneumatic and hydraulic. See Actuators, pneumatic-linear

DAMPERS, precision—electric
★ *Circle No.* 539

British Arca Regulators
D.E.V. Engineering
Drayton Regulator
Metropolitan Engineering
John Thompson Instrument

DAMPERS, precision—hydraulic
★ *Circle No.* 540

Bell Precision
British Arca Regulators
D.E.V. Engineering
Dowty Equipment
Drayton Regulator
George Hughes
H.M.L.
Integral
Kinetrol
Lockheed Precision Products
Maxam Power
Metropolitan Engineering
Reavell-Fahie
Schrader's Son, A.

DAMPERS, precision—pneumatic
★ *Circle No.* 541

British Arca Regulators
D.E.V. Engineering
Drayton Regulator
Lang Pneumatic
Maxam Power
Metropolitan Engineering
Stuart Davis
Schrader's Son, A.

DATA LOGGING EQUIPMENT
★ *Circle No.* 542

Airtech
Ampex Electronics
Benson Lehner (G.B.)
Blackburn Electronics
Bruce Peebles
C.N.S. Instruments
Decca Radar
De Havilland Propellers
Digital Engineering
Electro-Mechanical Systems
Electronic Associates
Elliott Nucleonics
Epsylon Industries
Ericsson Telephones
G.E.C.
General Controls
Gresham Developments
Hilger & Watts
Honeywell Controls
Integra Leeds
James Scott (Elec. Eng.)
Lancashire Dynamo
Lindars Automation
Lintronic
Monroe
Panellit
Plessey Co.
Solartron
Sound Diffusion
Southern Instruments
Sunvic Controls
Thermionic Products

DATA PROCESSING SYSTEMS (employing a digital computer)
★ *Circle No.* 543

A.E.I.
Armstrong Whitworth Equip.
Brush Electrical
Burroughs
Decca Radar
Digital Engineering
Electro-Mechanical Systems
EMI Electronics
English Electric
Epsylon Industries
Ferranti
Gallenkamp, A.
Gresham Developments
Harvey Electronics
Honeywell Controls
IBM United Kingdom
I.C.T.
Integra Leeds
Joyce Loebl
Newman Industries
Panellit
R.C.A. (G.B.)
Royston Instruments
Standard Telephones
Sunvic Controls
Winston Electronics

DATA TRANSMISSION. See Remote indication and control, electrical

DENSITY AND SPECIFIC GRAVITY CONTROLLERS. See also Controllers

DENSITY AND SPECIFIC GRAVITY CONTROLLERS — electric output
★ *Circle No.* 544

British Arca Regulators
Craven Electronics
Ekco Electronics
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
George Kent
Integral
Integra Leeds
Pye & Co., W. G.
Rotameter Mnfg.
Timothy Eaton

DENSITY AND SPECIFIC GRAVITY CONTROLLERS — pneumatic
★ *Circle No.* 545

British Arca Regulators
Crosby Valve & Eng.

★ For further details circle on card facing page 214

Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Foxboro-Yoxall
George Kent
Honeywell Controls
K.D.G. Instruments
Reavell-Pahle
Rotameter Mnfg.
Sunvic Controls
Taylor Controls

DENSITY AND SPECIFIC GRAVITY indicators, gases—specific gravity balance
★ *Circle No. 546*
Griffin & George
Samson Controls
Sigma Inst.

DENSITY AND SPECIFIC GRAVITY INDICATORS, liquids—air bubbler systems
★ *Circle No. 548*
Bailey Meters & Control
Bristol Inst.
Cheltenham Autocontrols
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Fisher Governor
Foxboro-Yoxall
George Kent
Honeywell Controls
Sunvic Controls
Taylor Controls
Williams & James

DENSITY AND SPECIFIC GRAVITY INDICATORS, liquids—balanced flow
★ *Circle No. 549*
Elliott Nucleonics
Taylor Controls

DENSITY AND SPECIFIC GRAVITY INDICATORS, liquids—displacement methods
★ *Circle No. 550*
Appleby & Ireland
Crosby Valve & Eng.
Electroflo Meters
Evershed & Vignoles
Fisher Governor
Sunvic Controls

DENSITY AND SPECIFIC GRAVITY INDICATORS, liquids—liquid purge systems
★ *Circle No. 551*
Electroflo Meters
Elliott Brothers
George Kent
K.D.G. Instruments
Taylor Controls

DENSITY AND SPECIFIC GRAVITY INDICATORS, liquids—other than the preceding types
★ *Circle No. 552*
Ekco Electronics
Firth Cleveland Instruments
Griffin & George
Integral
Isotope Developments
Pye & Co., W. G.
Rotameter Mnfg.

DEW-POINT INDICATORS. See Humidity indicators

DIAPHRAGMS, valve—leather
★ *Circle No. 553*
Black Automatic Controls
Graton & Knight
George Angus
Henry Beakbane
Metropolitan Engineering
Peri Controls

DIAPHRAGMS, valve—metallic
★ *Circle No. 554*
Appleby & Ireland
Black Automatic Controls
Elliott Brothers
Kelvin & Hughes
Mechanism
Peri Controls
Palatine Tool & Eng.
Saunders-Roe

DIAPHRAGMS, valve—plastic
★ *Circle No. 555*
Cooper & Co.
Delta Technical Services
Henry Beakbane
Saunders Valve

DIAPHRAGMS, valve—rubber
★ *Circle No. 556*
Crosby Valve & Eng.
Delta Technical Services
Dunlop Rubber
George Angus
Hall & Hall
N.G.N. Electrical
Peri Controls
Precision Rubbers
Ronald Trist
Saunders Valve

DIFFERENTIAL PRESSURE METERS. See also Flow-meters.

DIFFERENTIAL PRESSURE METERS—bellows-type meter
★ *Circle No. 557*
Appleby & Ireland
Bailey Meters & Control
Bristol Inst.
Cheltenham Autocontrols
Dewrance
Electroflo Meters
Evershed & Vignoles
Elliott Brothers
Elliott Nucleonics
Foxboro-Yoxall
George Kent
Honeywell Controls
James Gordon
John Thompson Instrument
Samson Controls
Sunvic Controls
Swartwout
Taylor Controls

DIFFERENTIAL PRESSURE METERS—force-balance
★ *Circle No. 558*
Boulton Paul Aircraft
Bristol Inst.
Cheltenham Autocontrols
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Fischer & Porter
Foxboro-Yoxall
George Kent
Honeywell Controls
James Gordon
Joseph Lucas (H. & C.)
Kandem Electrical
Kelvin & Hughes
Swartwout
Taylor Controls

DIFFERENTIAL PRESSURE METERS—liquid-filled manometers
★ *Circle No. 559*
Air Flow Developments
Bristol Inst.
Bryans Aeroequipment
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Foxboro-Yoxall
Fuel Efficiency
George Kent
Hobson, H. M.
James Gordon
John Thompson Instrument
Kandem Electrical
Nottingham Thermometer
Sydney Smith
Walker Crosweller

DIFFERENTIAL PRESSURE METERS—mercury float-type manometers
★ *Circle No. 560*
Bristol Inst.
Bryans Aeroequipment
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Foxboro-Yoxall
Fuel Efficiency
George Kent
James Gordon
John Thompson Instrument
Kandem Electrical
Kelvin & Hughes
Taylor Controls

DIFFERENTIAL PRESSURE METERS — weight-balance type meters
★ *Circle No. 561*
Electroflo Meters

DIFFERENTIAL PRESSURE METERS — others (specify type)
★ *Circle No. 562*
David Harcourt
Fielden Electronics
K.D.G. Instruments
Lintronic
Saunders-Roe

DIGITIZERS. See Converters, data-analogue-digital

DISPLACEMENT TRANSDUCERS (giving electrical output)—linear
★ *Circle No. 563*
Armstrong Whitworth Equip.
Automa Engineering
Boulton Paul Aircraft
British Arca Regulators
Brookhirst Igranic
Bruce Peebles
Brush Electrical
Bryans Aeroequipment
C.I.R.
C.N.S. Instruments
Craven Electronics
Dewrance
Electroflo Meters
Electro-Mechanical Systems
Elliott Nucleonics
Evershed & Vignoles
Fred Ferraris
Fielden Electronics
Graseby Instruments
G.E.C.
Giesler, C. F. R.
Grünther Ind. Developments
Hilger & Watts
I.E.C.-Sieger
James Scott Elec. Eng.
Lancashire Dynamo Elect.
Langham Thompson, J.
Louis Newmark
Paton Hawksley
Research & Control Inst.
Salford Elec. Instruments
S.E. Laboratories
Short Bros. & Harland
Smiths Industrial Inst.
Southern Instruments
Sperry Gyroscope
Swartwout
Telecommunication Inst.
Wayne Kerr Labs.

DISPLACEMENT TRANSDUCERS (giving electrical output)—rotary
★ *Circle No. 564*
Atkins, Robertson & W.
British Arca Regulators
Colvern
Electroflo Meters
Ericsson Telephones
Evershed & Vignoles
Fred Ferraris
Grünther Ind. Developments
Hilger & Watts
Lancashire Dynamo Elect.
Paton Hawksley
Racal Instruments
Short Bros. & Harland
Smith Industrial Inst.
Sperry Gyroscope
S.E. Laboratories
Woden Transformer

DISPLAY INDICATORS, in-line—electronic tube
★ *Circle No. 565*
Blackburn Electronics
British Central Elec.
Decca Radar
Digital Engineering
Ericsson Telephones
Firth Cleveland Instruments
K.G.M. Electronics
Lancashire Dynamo Elect.
Marconi, W. T.
Paton Hawksley
Racal Instruments
Rank Cintel
Southern Instruments
Standard Telephones
Timothy Eaton
Winston Electronics

DISPLAY INDICATORS, in-line—optical
★ *Circle No. 566*
Bailey, Sir W. H.
British Sarozal
Digital Engineering
Dowty Nucleonics
Hilger & Watts
Laurence Scott
Pullin, R. B.
Winston Electronics

DRAUGHT GAUGES AND INDICATORS
★ *Circle No. 567*
Airflow Developments
Appleby & Ireland
Bailey Meters & Control
Cambridge Instrument
Drayton Regulators
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Firth Cleveland Instruments
Fuel Efficiency
George Kent
James Gordon
John Thompson Instruments
K.D.G. Instruments
Kelvin & Hughes
Metropolitan Engineering
Sigma Inst. Co.
Sunvic Controls
Sydney Smith
Walker, Crosweller

DRIVES, constant-speed—electrical
★ *Circle No. 568*
Albert Mann Eng.
Brookhirst Igranic
Bruce Peebles
Brush Electrical
Crofts
Crompton Parkinson
English Electric
Elliott Nucleonics
Ericsson Telephones
G.E.C.
Graseby Instruments
Lancashire Dynamo Elect.
Newman Industries
Sanders (Electronics), W. H.
Servomex Controls
Vernons Industries
Welmec Corporation

DRIVES, constant-speed—hydraulic
★ *Circle No. 569*
Crofts
Dowty Hydraulic Units
H.M.L.
Hobson, H. M.
Integral
Joseph Lucas
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Stein Atkinson
Vickers-Armstrong

DRIVES, constant-speed—mechanical
★ *Circle No. 570*
Albert Mann Eng.
Birfield Industries
Crofts
General Controls
Graseby Instruments
Plessey Co.
Renold Chains

DRIVES, infinitely-variable-speed—electrical
★ *Circle No. 571*
A.E.I.
Albert Mann Eng.
Aveley Electric
British Sarozal
Brookhirst Igranic
Bruce Peebles
Crofts
Crompton Parkinson
Elliott Nucleonics
English Electric
Fuller Electric
G.E.C.
Graseby Instruments
Graton & Knight
Heenan & Froude
James W. Carr
Lancashire Dynamo Elect.
Lancashire Dynamo Nevelin
Laurence, Scott
M.T.E. Control Gear
Radiovisor Parent
Sanders (Electronics), W. H.
Servomex Controls
Timothy Eaton
Vernons Industries
Welmex Corporation

DRIVES, infinitely-variable-speed—hydraulic
★ *Circle No. 572*
Crofts
Dowty Hydraulic Units
Graton & Knight
H.M.L.
Integral
Joseph Lucas
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Stein Atkinson
Plessey Co.
Vickers
Vickers-Armstrong

DRIVES, infinitely-variable-speed—mechanical
★ *Circle No. 573*
Carter, B. & F.
Crofts
General Controls
Graseby Instruments
Graton & Knight
Miles-Hivolt
Tiltman Langley

DUST DETECTING EQUIPMENT
★ *Circle No. 574*
A.E.I.
Airflow Developments
B.M.B. Sales
Dallow Lambert
Griffin & George
James Gordon
Mancuna Engineering
Photoelectronics (M.O.M.)
Radiovisor Parent

DYNAMOMETERS
★ *Circle No. 575*
Anders Electronics
Aveley Electric
Craven Electronics
English Electric
Elliott Brothers
Evershed & Vignoles
Heenan & Froude
Int. Engineering Concess.
Langham, Thompson, J.
Laurence, Scott
Leland Instruments
Louis Newmark
Mawdsley's
Nalder Bros. & Thompson
Sigma Inst.
Small Electric Motors
Southern Instruments
Tinsley, H.

EDUCATIONAL EQUIPMENT. Specifically designed and suitable for establishments teaching control engineering
★ *Circle No. 576*
Air Trainers Link
A.P.T. Electronic Industries
Armstrong Whitworth Equip.
Automation Consultants
British Arca Regulators
British Sarozal
Bruce Peebles
C. & N. Electrical
Electro Methods
Elliott Brothers
Evershed & Vignoles
Farnell Instruments
Feedback
Harvey Electronics
Honeywell Controls
Maxam Power
Pioneer Designs
Plessey Nucleonics
Pye, W. G.
Rank Cintel
R.C.A. (G.B.)
Research & Control Inst.
Robinson & Partners, F. C.
Servomex Controls
Sanders (Electronics), W. H.
Saunders-Roe
Solartron
Tinsley, H.

ELECTRICAL CONDUCTIVITY CELLS
★ *Circle No. 577*
Alto Instruments
Cambridge Instrument
Doran Instrument
Electronic Switchgear
Evershed & Vignoles
Farnell Instruments
Foxboro-Yoxall
George Kent
Mullard Equipment
Pye & Co., W. G.
Research & Control Inst.
Stanley Palmer, G. A.
Wayne Kerr Labs.

ENGINE INDICATORS—electronic
★ *Circle No. 578*
Allied Electronics
British Physical Labs.
Bruce Peebles
Brush Electrical
Craven Electronics
Farnell Instruments
Giesler, C. F. R.
Joseph Lucas
Leland Instruments
Racal Instruments
S.E. Laboratories
Southern Instruments
Standard Telephones

ENGINE INDICATORS—mechanical
★ *Circle No. 579*
Dobbie McInnes
Hasler Telegraph Works
Icknield Engineering
Smith & Sons (England), S.
Stewart Aero Supply
Veeder-Root

ENGINE GOVERNORS—load control
★ *Circle No. 580*
Ardleigh Engineering
Dowty Fuel Systems
Joseph Lucas

ENGINE GOVERNORS—speed control
★ *Circle No. 581*
Ardleigh Engineering
Dewhurst & Partner
Dowty Fuel Systems
Foxboro-Yoxall
Hobson, H. M.
Icknield Engineering
Joseph Lucas

FACSIMILE EQUIPMENT
★ *Circle No. 582*
Creed & Company
Decca Radar
Marconi, W. T.
Muirhead
Telecommunications Inst.

FERRITE MATERIALS
★ *Circle No. 583*
Ferranti
Cole (Overseas), R. H.
Mullard
R.C.A. (G.B.)
Standard Telephones

FERRITE CORES
★ *Circle No. 584*
Cole (Overseas), R. H.
G.E.C.
Mullard
Neosid
R.C.A. (G.B.)
Standard Telephones

FILTERS, acoustic
★ *Circle No. 585*
Belclere Co.
Cooper & Co.
Dawe Instruments
Glass Developments

FILTERS, air
★ *Circle No. 586*
A. Schrader's Son
Alfred Bullows
Baldwin Industrial Controls
Benton & Stone
Birfield Industries
Bivac Air
B.M.B. Sales
Cheltenham Autocontrols
Davidson & Co.
Doulton Industrial Porcelains
Drayton Regulator
Dunlop Rubber
Electroflo Meters
Exactor
Fairey
Feeny & Johnson
Fleming Radio
George Kent
Harris Eng.
Holmes, W. C.
Infra Red Development
Int. Engineering Concess.
Intermit
Keith Blackman
Knitmesh

★ *For further details circle on card facing page 214*

Lacy Hulbert
Lockheed Precision Products
Matthews & Yates
Midland Pneumatic
Norgren, C. A.
Plenty & Son
Samuel Birkett
S.E. Laboratories
Simmonds Aerocessories
South London Elec. Equip.
Standard & Pochin Bros.
Stewart Aero Supply
Stream-Line Filters
Sturtevant Eng.
Sunvic Controls
Taylor Controls
Visco Engineering
Vokes
Volspray
Westinghouse Brake

FILTERS, electrical
★ *Circle No. 587*
Airtech
Aveley Electric
Belclere Co.
Belling & Lee
Bryan Savage
Cawkell
Claude Lyons
Epsylon Industries
Integral
K.G.M. Electronics
Lancashire Dynamo Elect.
Mullard Equipment
Plessey Co.
Radiospares
R.C.A. (G.B.)
Research & Control Inst.
S.E. Laboratories
Standard Telephones
Zenith Electric

FILTERS, fluid—microparticle
★ *Circle No. 588*
Auto-Klean Strainers
Birfield Industries
British Filters
Dunlop Rubber
Fairey
Industrial Hydraulics
Intermit
Keelavite Hydraulics
Liquid Systems
Lockheed Precision Products
Plenty & Son
Pratt Precision
S.E. Laboratories
Short Bros. & Harland
Sperry Gyroscope
Stream-Line Filters
Thermal Control
Vokes

FILTERS, fluid—standard
★ *Circle No. 589*
Auto-Klean Strainers
Avery Hardoll
Birfield Industries
British Filters
British Steam Specialities
Cooper & Co.
Doulton Industrial Porcelains
Fairey
Intermit
Keelavite Hydraulics
Knitmesh
Liquid Systems
Plenty & Son
Pratt Precision
Samuel Birkett
Simmonds Aerocessories
Stream-Line Filters
Vokes
Walker Crosweller

FILTERS, optical
★ *Circle No. 590*
Kodak
Leland Instruments
Optical Works
Strand Electric & Eng.
U.K. Optical

FIRE PROTECTION EQUIPMENT—aircraft
★ *Circle No. 591*
Aerocontacts
Klaxon
Miles-Hivolt
Stewart Aero Supply
Thermal Control Company

FIRE PROTECTION EQUIPMENT—industrial
★ *Circle No. 592*
British Sarozal
G.E.C.
George Angus
I.E.C.-Sieger
Klaxon
Magneta Time Co.
Radiovisor Parent
Simplex Electric
Sound Diffusion

FIRE PROTECTION EQUIPMENT—marine
★ *Circle No. 593*
G.E.C.
George Angus
I.E.C.-Sieger
Klaxon

FLAME FAILURE EQUIPMENT
★ *Circle No. 594*
A.E.I.
Bailey Meters & Control
Danfoss
Elcontrol
Electrotechnic Ltd.
Ether
Fireye Controls
Fuel Efficiency
Honeywell Controls
Horstmann Gear
John Thompson Instrument
K.D.G. Instruments
Lancashire Dynamo Elect.
M.B. Metals
Newman Industries
Parkinson Cowan Inst.
Parmeko
Perl Controls
Photoelectronics (M.O.M.)
Radiovisor Parent
Rheostatic Co.
Sauter Controls
Stonebridge Electrical
Teddington Ind. Equip.

FLAMEPROOF ENCLOSURES
★ *Circle No. 595*
Simplex Electric

FLOW CONTROLLERS. See also Controllers

FLOW CONTROLLERS—electric output
★ *Circle No. 596*
Alto Instruments
Appleby & Ireland
Bailey Meters & Control
Bayham
Black Automatic Controls
Bristol Inst.
Delta Technical Services
Dewrance
Electroflo Meters
Elliott Brothers
Evershed & Vignoles
Firth Cleveland Instruments
Fuel Efficiency
George Kent
James Gordon
Kandem Electrical
Lintronic
Londex
Normalair
Plessey Co.
Rotameter Mnfg.
Sauter Controls
Stanley Palmer, G. A.
Swartwout
Teddington Ind. Equip.

FLOW CONTROLLERS—pneumatic output
★ *Circle No. 597*
Alto Instruments
A. Schrader's Son
Bailey Meters & Control
Benton & Stone
Birfield Industries
British Arca Regulators
Bristol Inst.
Cheltenham Autocontrols
Delta Technical Services
Elec. Steam & Mining
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Fischer & Porter
Foxboro-Yoxall
George Kent
Honeywell Controls
James Gordon
Martonair
Normalair
Reavell-Fahie
Rotameter Mnfg.
Samson Controls
Sauter Controls
Simmonds Aerocessories
Stanley Palmer, G. A.
Stuart Davis
Sunvic Controls
Swartwout
Taylor Controls

FLOW DIVIDERS. See Valves, fluid

FLOWMETERS—area, piston-type
★ *Circle No. 598*
Armstrong Whitworth Equip.
Bailey Meters & Control
Black Automatic Controls
George Kent
Honeywell Controls
Lindars Automation
Liquid Systems
Thomas Ashworth

FLOWMETERS—area, rotameter
★ *Circle No. 599*
Drallim Industries
Electro-Mechanical Systems
Evershed & Vignoles
Fischer & Porter
Platon, G. A.
Rotameter Mnfg.

FLOWMETERS—Dall-tube
★ *Circle No. 600*
Evershed & Vignoles
George Kent

FLOWMETERS—digital
★ *Circle No. 601*
Bryans Aeroequipment
De Havilland Propellers
Digital Engineering
Hobson, H. M.
Integral
Lindars Automation
Radiatron
S.E. Laboratories

FLOWMETERS—electromagnetic
★ *Circle No. 602*
Alto Instruments
Bristol Inst.
Electro Mechanical System
Fischer & Porter
Foxboro-Yoxall
H. M. Hobson
Lintronic
Measurement Limited
S.E. Laboratories
Stanley Palmer, G. A.

FLOWMETERS—flume
★ *Circle No. 603*
Electroflo Meters
Elliott Brothers
Foxboro-Yoxall
George Kent
Walker Crosweller

FLOWMETERS—hot-wire anemometer
★ *Circle No. 604*
Lintronic
Tinsley, H.

FLOWMETERS—momentum (axial flow)
★ *Circle No. 605*
Fred Ferraris
George Kent

FLOWMETERS—nozzle
★ *Circle No. 606*
Bailey Meters & Control
Bristol Inst.
Cheltenham Autocontrols
Electroflo Meters
Kelvin & Hughes

FLOWMETERS—orifice plate
★ *Circle No. 607*
Air Flow Developments
Appleby & Ireland
Bailey Meters & Control
Black Automatic Controls
Cheltenham Autocontrols
Dewrance
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Fischer & Porter
Foxboro-Yoxall
Fuel Efficiency
George Kent
Honeywell Controls
John Thompson Instrument
Kandem Electrical
Keelavite Hydraulics
Kelvin & Hughes
Negretti & Zambra
Platon, G. A.
Rotameter Mnfg.
Samson Controls
Sunvic Controls
Swartwout
Taylor Controls
Tylors of London
Walker Crosweller

FLOWMETERS—pitot tube
★ *Circle No. 608*
Air Flow Developments
Black Automatic Controls
Bristol Inst.
Cheltenham Autocontrols
Elliott Brothers
Elliott Nucleonics
Electroflo Meters
Evershed & Vignoles
Foxboro-Yoxall
George Kent
Griffin & George
Negretti and Zambra
Taylor Controls
Walker Crosweller

FLOWMETERS—positive displacement
★ *Circle No. 609*
Avery-Hardoll
Black Automatic Controls
Cheltenham Autocontrols
Gilbarco
Leeds Meter
Liquid Systems
Measurement Limited
Tylors of London

FLOWMETERS—propeller
★ *Circle No. 610*
Cheltenham Autocontrols
De Havilland Propellers
Electro-Mechanical Systems
Firth Cleveland Instruments
Fred Ferraris
George Kent
Hobson, H. M.
Integral
Leeds Meter
M.L. Aviation Company
S.E. Laboratories
Tylors of London

FLOWMETERS—target
★ *Circle No. 611*
Cheltenham Autocontrols
Lindards Automation
Londex

FLOWMETERS—ultrasonic
★ *Circle No. 612*
British Sarozal

FLOWMETERS—V-notch
★ *Circle No. 613*
Bristol Inst.
Cheltenham Autocontrols
Electroflo Meters
Elliott Brothers
George Kent
Walker Crosweller

FLOWMETERS—venturi tube
★ *Circle No. 614*
Bailey Meters & Control
Black Automatic Controls
Bristol Inst.
Cheltenham Autocontrols
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
George Kent
Fuel Efficiency
Honeywell Controls
John Thompson Instrument
Kelvin & Hughes
Samson Controls
Walker Crosweller

FLOWMETERS—weir
★ *Circle No. 615*
Bristol Inst.
Cheltenham Autocontrols
Electroflo Meters
Elliott Brothers
George Kent
Walker Crosweller

FLUX METERS. See Magnetic flux meters and Neutron flux meters

FORCE TRANSDUCERS (giving electrical output)
★ *Circle No. 616*
Armstrong Whitworth Equip.
B. & K. Labs.
Boulton Paul Aircraft
British Arca Regulators
British Sarozal
Bryans Aeroequipment
Davy & United Instruments
Electroflo Meters
Electro-Mechanical Systems
Evershed & Vignoles
Fairey
Langham Thompson, J.
Lintronic
Paton Hawksley
R.C.A. (G.B.)
Salford Elec. Instruments
Saunders-Roe
S.E. Laboratories
Solartron
Woden Transformer

FREQUENCY METERS—electronic
★ *Circle No. 617*
A.E.I.
Airmec
Aveley Electric
B. & K. Labs.
Bryans Aeroequipment
Bryan Savage
Claude Lyons
Dawe Instruments
Ericsson Telephones
Farnell Instruments
Giesler, C. F. R.
Grinther Ind. Developments
Honeywell Controls
Integra Leeds
Integral
Lancashire Dynamo Elect.
Langham Thompson, J.
Marconi Instruments
Measuring Instruments
Metrix Instruments
Nash & Thompson
Peto Scott
Racal Instruments
Rank Cintel
Telemechanics
Venner Electronics
Sanders (Electronics), W. H.
Winston Electronics

FREQUENCY METERS—vibrating reed
★ *Circle No. 618*
Aveley Electric
Dowty Nucleonics
Metrix Instruments
Salford Elec. Instruments
White Electrical Inst.

FREQUENCY RESPONSE ANALYSERS—electromechanical
★ *Circle No. 619*
Muirhead
Servo Consultants

FREQUENCY RESPONSE ANALYSERS—electronic
★ *Circle No. 620*
Aveley Electric
B. & K. Labs.
Dawe Instruments
De Havilland Propellers
Integra Leeds
James Scott Elec. Eng.
Louis Newmark
Marconi Instruments
Muirhead
Peto Scott
R.C.A. (G.B.)
Servo Consultants
Servomex Controls
Short Bros. & Harland
Solartron
Standard Telephones
Wayne Kerr Labs.
Winston Electronics

FUEL METERING EQUIPMENT (aircraft)
★ *Circle No. 621*
Armstrong Whitworth Equip.
Avery-Hardoll
Dowty Fuel Systems
Electro-Mechanical Systems
Firth Cleveland Instruments
George Kent
Hobson, H. M.
Integral
Miles-Hivolt
Rotameter Mnfg.
S.E. Laboratories
Stewart Aero Supply

GAITERS, RUBBER
★ *Circle No. 622*
Dunlop Rubber
Hall & Hall
Henry Beakbane
John Bull Rubber

GALVANOMETERS
★ *Circle No. 623*
Anders Electronics
Aveley Electric
Baldwin Industrial Controls
British Sarozal
Cambridge Instruments
Dobbie McInnes
Doran Instrument
Electroflo Meters
Elliott Brothers
Evans Electroselenium
Farnell Instruments
Films & Equipment
Griffin & George
Gambrell Bros.
John Thompson Instrument
Measuring Instrument
New Electronic Products
Page Engineering
Pye, W. G.
Sangamo Weston
Savage & Parsons
S.E. Laboratories
Taylor Electrical
Tinsley, H.
White Electrical Instruments
Wilkinson (Croydon), L.

GAS ANALYSERS. See Analytical instruments

GEARBOXES, miniature precision—differential
★ *Circle No. 624*
Davall Gear
Fred Ferraris
Graseby Instruments
Laurence Scott
Muffett, S. H.
Pioneer Designs
Sealey Engineering
White & Riches
Sanders (Electronics), W. H.

GEARBOXES, miniature precision—reduction
★ *Circle No. 625*
Cambridge Instruments
Carter, B. & F.
Davall Gear
Devon Instruments
Gear Grinding Co.
General Controls
Graseby Instruments
H. & B. Precision Eng.
Harvey Electronics
Icknield Engineering
Klaxon
Laurence Scott
Muffett, S. H.
Pioneer Designs
Plessey Co.
Robert Pringle & Sons
Pullin, R. B.
Sanders (Electronics), W. H.
Sealex Engineering
Servo Consultants
Servo Units
Shackman, D.
Smith & Sons (England), S.
Sperry Gyroscope
Spencer Components
Thomas Mercer
White & Riches

GEARING, precision
★ *Circle No. 626*
Birfield Industries
Graseby Instruments
Davall Gear
Fred Ferraris
Gear Grinding Co.
General Controls
George Angus
Glass Developments
Harvey Electronics
H. & B. Precision Eng.
Icknield Engineering
Laurence Scott
Louis Newmark
Muffett, S. H.
Pioneer Designs
Plessey Co.
Pullin, R. B.
Robert Pringle & Sons
Sanders (Electronics), W. H.
Sealey Engineering
Servomex Controls
Spencer Components
Sperry Gyroscope
Thomas Mercer

GENERATORS. See also Tachometers

GENERATORS—function
★ *Circle No. 627*
Advance Components

★ *For further details circle on card facing page 214*

Armstrong Whitworth Equip.
Bruce Peebles
Dobbie McInnes
Feedback
Lancashire Dynamo Elect.
Miles-Hivolt
Mortley Sprague
Servomex Controls
Solartron
Stewart Aero Supply

GENERATORS—noise
★ *Circle No.* 628
Aveley Electric
Bruce Peebles
Claude Lyons
Dawe Instruments
Decca Radar
Electronic Associates
Farnell Instruments
Ferranti
Marconi Instruments
Sanders (Electronics), W. H.
Servomex Controls

GENERATORS—pulse
★ *Circle No.* 629
Aveley Electric
Bradley, G. & E.
Bruce Peebles
Claude Lyons
Conventry Controls
Cossor Instruments
Coventry Instruments
Craven Electronics
Dawe Instruments
Dobbie McInnes
EMI Electronics
Ericsson Telephones
Farnell Instruments
Fleming Radio
Kasama Electronics
Kendall & Mousley
Lintronic
Marconi Instruments
Marshall of Cambridge
Miles-Hivolt
Mullard Equipment
Nagard
Panax Equipment
Rank Cintel
Research & Control Inst.
Servomex Controls
Solartron
Sunvic Controls
Taylor Electrical
Wayne Kerr Labs.
Winston Electronics

GENERATORS—sweep
★ *Circle No.* 630
Allied Electronics
Armstrong Whitworth Equip.
Aveley Electric
Bruce Peebles
Claude Lyons
Cossor Instruments
Dawe Instruments
Decca Radar
Marconi Instruments
Metrix Instruments
Rank Cintel
Taylor Electrical

GENERATORS—synchronous
★ *Circle No.* 631
Aveley Electric
Bruce Peebles
English Electric
Evershed & Vignoles
Marconi Instruments
Vernons Industries
Walter Jones
Wright Electric Motors

GENERATORS—ultrasonic
★ *Circle No.* 632
British Sarozal
Bruce Peebles
Craven Electronics
Dawe Instruments
Farnell Instruments
Glass Developments
Lintronic
Mullard Equipment
Metrix Instruments
Wayne Kerr Labs.

GENERATORS—wave
★ *Circle No.* 633
Aveley Electric
Bruce Peebles
Claude Lyons
Furzehill Labs.
Marconi Instruments
Rank Cintel
Research & Control Inst.
Servo Consultants
Servomex Controls
Telemechanics

GLOSSMETERS, continuous reading. See **Photometric instruments**

GYRO CALIBRATION EQUIPMENT
★ *Circle No.* 634
Bryans Aeroequipment
English Electric
Graseby Instruments
Racal Instruments
Solartron

GYROS—directional
★ *Circle No.* 635
Aerocontacts
Brown, S. G.
Ferranti
Kelvin & Hughes
Louis Newmark
Pullin, R. B.
Sperry Gyroscope
Stewart Aero Supply

GYROS—integrating
★ *Circle No.* 636
English Electric
Ferranti
Pullin, R. B.
Sperry Gyroscope

GYROS—miniature
★ *Circle No.* 637
Brown, S. G.
De Havilland Propellers
English Electric
Ferranti
Graseby Instruments
Sperry Gyroscope

GYROS—pilots
★ *Circle No.* 638
Aerocontacts
Brown, S. G.
Sperry Gyroscope
Stewart Aero Supply

GYROS—rate
★ *Circle No.* 639
Brown, S. G.
De Havilland Propellers
Elliott Brothers
English Electric
Ferranti
Graseby Instruments
Kelvin & Hughes
Louis Newmark
Muirhead
Pullin, R. B.
Sperry Gyroscope

GYROS—stabilizer
★ *Circle No.* 640
Brown, S. G.
English Electric
Ferranti
Louis Newmark
Pullin, R. B.

GYROS—vertical
★ *Circle No.* 641
Brown, S. G.
Ferranti
Louis Newmark
Muirhead
Pullin, R. B.
Sperry Gyroscope

HARMONIC ANALYSERS—electronic
★ *Circle No.* 642
Airmec
Aveley Electric
Claude Lyons
Craven Electronics
Dawe Instruments
Farnell Instruments
Furzehill Labs.
James Scott Elec. Eng.
Marconi Instruments
Muirhead
Royston Instruments
Servo Consultants
Servomex Controls
Wayne Kerr Labs.

HARMONIC ANALYSERS—mechanical
★ *Circle No.* 643
Servo Consultants
Stanley & Co., W. F.

HUMIDITY INDICATORS, continuous reading—dew point methods
★ *Circle No.* 644
Birlec
Foxboro-Yoxall
Integra Leeds
Measuring Instruments
Nottingham Thermometer
Research & Control Inst.
Shaw Moisture Meters
Taylor Controls

HUMIDITY INDICATORS, continuous reading—hygrometers
★ *Circle No.* 645
B. & K. Labs.
Cambridge Instrument
Darton, F.
Electrical Thermometer
Elliott Brothers
Foxboro-Yoxall
Fred Ferraris
Fuel Efficiency
Gallenkamp, A.
Headland Eng. Developments
Honeywell Controls
Hymatic Engineering
James Gordon
Leland Instruments
Negretti & Zambra
Plessey Co.
Reynolds & Branson
Shaw Moisture Meters
Short & Mason
Stanley & Co., W. F.
Zeal, G. H.

HUMIDITY INDICATORS, continuous reading — other than the preceding types
★ *Circle No.* 646
Electroflo Meters
Electro Methods
Headland Eng. Developments
Infra Red Development
Lock, A. M.
Sauter Controls
Shaw Moisture Meters

ICE WARNING INDICATORS
★ *Circle No.* 647
Armstrong Whitworth Equip.
Engel & Gibbs
Sangamo Weston

INDICATORS, in-line. See **Display indicators**

INDUCTION REGULATORS
★ *Circle No.* 648
English Electric
Laurence Scott
Mawdsley's

INDUCTORS
★ *Circle No.* 649
Ardente Acoustic Lab.
Gardners Radio
Newport Instruments
Sykes, W. R.
Tinsley, H.
Transformer & Electric

INFRA-RED ANALYSERS. See **Analytical instruments**

INFRA-RED DETECTORS. See **Radiation detectors**

INFRA-RED SOURCES
★ *Circle No.* 650
G.E.C.
Hilger & Watts
R.C.A. (G.B.)

INTEGRATORS—electrical
★ *Circle No.* 651
Bristol Inst.
Electroflo Meters
Elliott Brothers
Foxboro-Yoxall
Fuel Efficiency
George Kent
Miles-Hivolt

INTEGRATORS—electronic
★ *Circle No.* 652
Air Trainers Link
Blackburn Electronics
Bristol Inst.
Bruce Peebles
Craven Electronics
Electronic Associates
Eliott Brothers
Firth Cleveland Instruments
Honeywell Controls
Joyce Loebl
Lancashire Dynamo Elect.
Marshall of Cambridge
Miles-Hivolt
Newman Industries
Perkin-Elmer
Pye, W. G.
Research & Control Inst.
Royston Instruments
Short Bros. & Harland
Solartron
Saunders-Roe

INTEGRATORS—electromechanical
★ *Circle No.* 653
Air Trainers Link
Blackburn Electronics
Bristol Inst.
Devon Instruments
Digital Engineering
Electro Methods
Elliott Brothers
Fuel Efficiency
George Kent
Joyce Loebl
Kelvin & Hughes
Miles-Hivolt
Radiatron
Servomex Controls
Solartron
Sperry Gyroscope
Taylor Controls
White & Riches

INTEGRATORS—mechanical
★ *Circle No.* 654
Air Trainers Link
Bailey Meters & Control
Bristol Inst.
Devon Instruments
Electroflo Meters
Elliott Brothers
Fuel Efficiency
George Kent
John Thompson Instrument
Miles-Hivolt
Stanley & Co., W. F.

INTENSIFIERS, hydraulic
★ *Circle No.* 655
Bell Precision
Baldwin Industrial Controls
Dunlop Rubber
Fawcett Preston
Keelavite Hydraulics
Maxam Power
Power Jacks

ION EXCHANGE EQUIPMENT
★ *Circle No.* 656
Elga Products
Gallenkamp A.
Griffin & George
Permutit

ISOTOPES, radioactive
★ *Circle No.* 657
Baldwin Industrial Controls
Hawker Siddeley Nuclear
Research & Control Inst.

JOINTING MATERIALS
★ *Circle No.* 658
Cooper & Co.
Hall & Hall
James Walker
James W. Carr
Johnson Matthey

JOINTS, UNIVERSAL
★ *Circle No.* 659
Baty, J. E.
Birfield Industries
James W. Carr
Mollart Engineering

KERR CELLS
★ *Circle No.* 660
Lintronic

LEAK DETECTORS, mass spectrometer
★ *Circle No.* 661
Appleby & Ireland
Edwards High Vacuum
Gallenkamp, A.
Leybold Vacuum Sales
20th. Century Electronics

LEVEL DETECTORS, LIQUID—infra red
★ *Circle No.* 662
Appleby & Ireland
Bryans Aeroequipment
Electroflo Meters
Glass Developments
Infra Red Development
K.D.G. Instruments
Taylor Controls
Wallace & Tiernan

LEVEL DETECTORS, LIQUID—balanced diaphragm
★ *Circle No.* 663
Bristol Inst.
Cheltenham Autocontrols
Electroflo Meters
Elliott Brothers
Evershed & Vignoles
Fisher Governor
Foxboro-Yoxall
Fuel Efficiency
James Gordon
K.D.G. Instruments
S.E. Laboratories
Taylor Controls

LEVEL DETECTORS, LIQUID—ball-float
★ *Circle No.* 664
Automation Consultants
Bamford, F.
Bayham
Black Automatic Controls
Bristol Inst.
Brookhirst Igranic
Bruce Peebles
Danfoss
Drayton Regulator
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Firth Cleveland Instruments
Fischer & Porter
Fisher Governor
G.E.C.
Ionic Instruments
Kandem Electrical
Laurence Scott
Londex
Sauter Controls
Smith Industrial Inst.
Sunvic Controls
Telemeters
Tully Engineering

LEVEL DETECTORS, LIQUID—chain or tape
★ *Circle No.* 665
Bristol Inst.
Elliott Brothers
Foxboro-Yoxall
Parkinson Cowan Inst.
Sauter Controls

LEVEL DETECTORS, LIQUID—electrical capacitance
★ *Circle No.* 666
Ariel Sound
Automa Engineering
Craven Electronics
Elcontrol
Electronic Switchgear
Farnell Instruments
Fielden Electronics
Firth Cleveland Instruments
G.E.C.
Grünther Ind. Developments
Headland Eng. Developments
Integra Leeds
Ionic Instruments
James Gordon
Lancashire Dynamo Elect.
Lock, A. M.
Newman Industries
Plessey Company
Radiovisor Parent
Thomas Automation
Vidor Batteries
Wayne Kerr Labs.

LEVEL DETECTORS, LIQUID—float valve
★ *Circle No.* 667
Automation Consultants
Avery-Hardoll
Drayton Regulator
Elliott Nucleonics
Fisher Governor
Flight Refuelling
James Gordon
Ionic Instruments

LEVEL DETECTORS, LIQUID—force-balance diaphragm
★ *Circle No.* 668
Bailey Meters and Control
Bristol Inst.
Cheltenham Autocontrols
Dewrance
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Foxboro-Yoxall
Honeywell Controls
Mead & Phasey
Taylor Controls

LEVEL DETECTORS, LIQUID—force-balance displacer
★ *Circle No.* 669
Crosby Valve & Eng.
Electroflo Meters
Evershed & Vignoles
Fisher Governor
Sunvic Controls

LEVEL DETECTORS, LIQUID—magnetic float
★ *Circle No.* 670
Bayham
Flight Refuelling
Ionic Instruments
Kingston Control Systems
Londex
Rotameter Mnfg.

LEVEL DETECTORS, LIQUID—mercury manometer
★ *Circle No.* 671
Bristol Inst.
Bryans Aeroequipment
Combustion Instruments
Darton, F.
Electrical Thermometer
Electroflo Meters
Elliott Brothers
Foxboro-Yoxall
George Kent
Glass Developments
Hobson, H. M.
John Thompson Instrument
Taylor Controls

LEVEL DETECTORS, LIQUID—nuclear radiation
★ *Circle No.* 672
Baldwin Industrial Controls
Bruce Peebles
Craven Electronics
Isotope Developments
Lock, A. M.
Panax Equipment
Research & Control Inst.
Vidor Batteries

LEVEL DETECTORS, LIQUID—opposed diaphragm
★ *Circle No.* 673
Bristol Inst.
Elliott Brothers
K.D.G. Instruments
Swartwout

LEVEL DETECTORS, LIQUID—oscillator type
★ *Circle No.* 674
Firth Cleveland Instruments
Telemeters

LEVEL DETECTORS, LIQUID—pressure gauge systems
★ *Circle No.* 675
Appleby & Ireland
Bailey Meters & Control
Bristol Inst.
Budenberg Gauge
Combustion Instruments
Delta Technical Services
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Fielden Electronics
Firth Cleveland Instruments
Foxboro-Yoxall
Fuel Efficiency
Kandem Electrical
George Kent
Hobson, H. M.
Honeywell Controls
James Gordon
K.D.G. Instruments
Negretti & Zambra
Payne & Griffiths
Pillinger, G. C.
Salford Elec. Instruments
Wallace & Tiernan

LEVEL DETECTORS, LIQUID—thermometer bulb
★ *Circle No.* 676
Bristol Inst.
Elliott Brothers
Fielden Electronics
Headland Eng. Dev.

LEVEL DETECTORS, LIQUID—torque-tube displacer
★ *Circle No.* 677
Dewrance
Fisher Governor
Swartwout

LEVEL DETECTORS, LIQUID—other than the preceding types
★ *Circle No.* 678
Brookhirst Igranic
Davy & United Instruments

★ *For further details circle on card facing page 214*

Elcontrol
Evershed & Vignoles
Firth Cleveland Instruments
Fisher Governor
George Kent
Hobson, H. M.
Ionic Instruments
K.D.G. Instruments
Lancashire Dynamo Elect.
Londex
Newman Industries
Radiovisor Parent
Research & Control Inst.
Robinson & Partners, F. C.
Saunders-Roe
Stanley Palmer, G. A.
Teddington Ind. Equip.

LEVEL DETECTORS, SOLID—electrical capacitance ★ *Circle No.* 679
Ariel Sound
Armstrong Whitworth Equip.
Automa Engineering
Bailey Meters & Control
Craven Electronics
Elcontrol
Electronic Switchgear
Farnell Instruments
Fielden Electronics
Grünther Ind. Developments
Integra Leeds
Lancashire Dynamo Elect.
Lock, A. M.
Radiovisor Parent
Thomas Automation
Vidor Batteries

LEVEL DETECTORS, SOLID—electrical contact ★ *Circle No.* 680
Automation Systems
Bruce Peebles
Craven Electronics
Evershed & Vignoles
Lancashire Dynamo Elect.
Lindars Automation
Londex
Magnetic Equipment
Radiovisor Parent

LEVEL DETECTORS, SOLID—diaphragm unit ★ *Circle No.* 681
Black Automatic Controls
Elliott Brothers
Firth Cleveland Instruments
Lindars Automation
Londex
Magnetic Equipment
Sinex Engineering

LEVEL DETECTORS, SOLID—gamma-ray absorption ★ *Circle No.* 682
Bruce Peebles
Isotope Developments
Lock, A. M.
Panax Equipment
Peto Scott
Vidor Batteries

LEVEL DETECTORS, SOLID—rotating paddle ★ *Circle No.* 683
Dobbie McInnes
Elec. Steam & Mining
Londex
Williams & James

LEVEL DETECTORS, SOLID—weighing methods ★ *Circle No.* 684
Bruce Peebles
Davy & United Instruments
General Controls
Research & Control Inst.
Taylor Controls

LOAD CELLS. See also **Weighers, industrial**

LOAD CELLS—electrical ★ *Circle No.* 685
Albert Mann Eng.
Armstrong Whitworth Equip.
B. & K. Labs.
Boulton Paul Aircraft
Craven Electronics
Davy & United Instruments
Elliott Brothers
Elliott Nucleonics
Ericsson Telephones
Langham Thompson, J.
Lintronic
Research & Control Inst.
Salford Elec. Instruments
Saunders-Roe
S.E. Laboratories
Southern Instruments

LOAD CELLS—mechanical ★ *Circle No.* 686
Richardson Scale

MACHINE TOOL CONTROL SYSTEMS—continuous contour ★ *Circle No.* 687
A.E.I.
Asquith Electrics
Bell Precision
British Sarozal
Brush Electrical
Electro-Hydraulics
Electro-Mechanical Systems
Ferranti
General Electric
Lancashire Dynamo Elect.
Royston Instruments
Sigma Instruments
Southern Instruments
Sperry Gyroscope
Stein Atkinson
Telecommunication Inst.
Thomas Mercer (Air Gauges)
Welmec Corporation

MACHINE TOOL CONTROL SYSTEMS—static positioning ★ *Circle No.* 688
A.E.I.
Airmec
Armstrong Whitworth Equip.
Asquith Electrics
Brookhirst Igranic
Bruce Peebles
Brush Electrical
Electro Hydraulics
Ericsson Telephones
G.E.C.
Industrial Technics
James Scott Elec. Eng.
Lancashire Dynamo Elect.
Lintronic
Mawdsley's
Mullard Equipment
Plessey Co.
Royston Instruments
Sanders (Electronics), W. H.
Sperry Gyroscope
Stein Atkinson
Teddington Ind. Equip.
Teledictor
Telecommunication Inst.
Welmec Corporation

MAGNETIC FLUX METERS ★ *Circle No.* 689
A.E.I.
British Sarozal
Cambridge Instrument
Cole (Overseas), R. H.
Decca Radar
Lancashire Dynamo Elect.
Newport Instrument
Pye, W. G.
Salford Elec. Instruments
Welmec Corporation
White & Riches

MAGNETIC MATERIALS ★ *Circle No.* 690
Darwins
Ferranti
Mullard
Neosid
Plessey Co.
Telcon Magnetic Cores

MAGNETIC TAPE ★ *Circle No.* 691
Ampex Electronics
Decca Radar
Electro-Mechanical Systems
Epsylon Industries
Holiday & Hemmerdinger
Kodak
Lee Products
Minnesota Mining & Mfg.
M.S.S. Recording
R.C.A. (G.B.)

MAGNETIC TAPE RECORDERS, industrial ★ *Circle No.* 692
Aerocontacts
Ampex Electronics
Aveley Electric
B. & K. Labs.
Bradmatic
Data Recording
Decca Radar
Electro-Mechanical Systems
EMI Electronics
Epsylon Industries
Gresham Developments
Hartley Electromotives
Holiday & Hemmerdinger
K.G.M. Electronics
Louis Newmark
Marconi I.M.Com.
New Electronic Products
Plessey Co.
Rank Cintel
R.C.A. (G.B.)
Royston Instruments
Sanders (Electronics), W. H.
Solartron
Thermionic Products
Truvox
Welmec Corporation

MAGNETIC WIRE RECORDERS, industrial ★ *Circle No.* 693
Bell Precision

MAGNETS, permanent ★ *Circle No.* 694
British Sarozal
Darwins
Griffin & George
James W. Carr
Johnson Matthey
Mullard
Oliver Pell
Permag Equipment
Preformations
Pye, W. G.

MAGSLIPS. See **Remote control, electrical**

METADYNE. See **Amplifiers, rotating electrical**

METAL DETECTORS ★ *Circle No.* 695
Automa Engineering
Bruce Peebles
Craven Electronics
Fuller Electric
Metal Detection
Rank Cintel
R.C.A. (G.B.)

MOISTURE CONTENT INDICATORS—paper ★ *Circle No.* 696
Cambridge Instrument
Honeywell Controls
Marconi Instruments
Plessey Co.
Research & Control Inst.
Shaw Moisture Meters
Thomas Ashworth
Timothy Eaton

MOISTURE CONTENT INDICATORS — sand, granular solids ★ *Circle No.* 697
Bruce Peebles
Cawkell
Farnell Instruments
Lancashire Dynamo Elect.
Plessey Co.
Shaw Moisture Meters
Thomas Ashworth

MOISTURE CONTENT INDICATORS—textile fibres ★ *Circle No.* 698
Fielden Electronics
Honeywell Controls
Marconi Instruments
Plessey Co.
Record Elec.
Reynolds & Branson
Shaw Moisture Meters
Thomas Ashworth
Timothy Eaton

MOISTURE CONTENT INDICATORS—wood ★ *Circle No.* 699
Dawe Instruments
Farnell Instruments
Marconi Instruments
Shaw Moisture Meters
Thomas Ashworth

MOISTURE CONTENT INDICATORS—other types ★ *Circle No.* 700
B. & K. Labs.
Bruce Peebles
Edwards High Vacuum
Elliott Brothers
Fuel Efficiency
Marconi Instruments
Shaw Moisture Meters
Thomas Ashworth

MOTOR CONTROLLERS, electric ★ *Circle No.* 701
A.E.I.
Airmec
Allen West & Co.
Arrow Electric Switches
Asquith Electrics
British Central Elec.
British Elec. Resistance Co.
British Federal Welder
Brit. Klockner Switchgear
British Sarozal
Brookhirst Igranic
Brook Motors
Bruce Peebles
Brush Electrical
Claude Lyons
Dewhurst & Partner
Electrical Apparatus
Electric Remote Control
Electro Mechanical Mfg.
Electro Methods
English Electric
George Ellison
K.G.M. Electronics
Lancashire Dynamo Elect.
Lancashire Dynamo Nevelin
Laurence Scott
Morecambe Electrical
M.T.E. Control Gear
Parmeko
Pelapone Engines
Sanders (Electronics), W. H.
Servomex Controls
Sharp Control Gear
Siemens-Schuckert
Simmons Electrical Winding
Square D
Teddington Ind. Equip.
Timothy Eaton
Vlasto Clark & Watson
Watford Electric

MOTORS, rotary electric, a.c. servo—drag-cup ★ *Circle No.* 702
British Central Elec.
Brown, S. G.
Evershed & Vignoles

MOTORS, rotary electric, a.c. servo—hysteresis ★ *Circle No.* 703
British Central Elec.
Brown, S. G.
Evershed & Vignoles
Kelvin & Hughes
Laurence Scott
Muirhead
Smith Industrial Inst.
Sterling Instruments
Vactric Control Equipment
Walter Jones
Welmec Corporation

MOTORS, rotary electric, a.c. servo—squirrel cage ★ *Circle No.* 704
British Central Elec.
Brook Motors
Brown, S. G.
Brush Electrical
Drayton Regulator
English Electric
Evershed & Vignoles
Fractional H.P. Motors
Fuel Efficiency
G.E.C.
George Kent
Honeywell Controls
Kelvin & Hughes
Klaxon
Laurence Scott
Mawdsley's
Mortley Sprague Co.
Newman Industries
Parvalux
Plessey Co.
Pullin, R. B.
Simmons Electrical Winding
Small Electric Motors
Vactric Control Equipment
Walter Jones
Welmec Corporation
Wright Electric Motors

MOTORS, rotary electric, a.c. servo—torque ★ *Circle No.* 705
British Central Elec.
Brown, S. G.
De Havilland Propellers
Evershed & Vignoles
G.E.C.
Klaxon
Laurence Scott
Louis Newmark
Muirhead
Rheostatic Co.
Small Electric Motors
Sperry Gyroscope
Walter Jones
Woden Transformer

MOTORS, electric, d.c. servo—split-armature, permanent magnet ★ *Circle No.* 706
British Central Elec.
Brush Electrical
Electro Methods
Evershed & Vignoles
Klaxon
Laurence Scott
Newton Brothers (Derby)
Vactric Control Equipment
Western Mfg. Reading

MOTORS, electric, d.c. servo—split-armature, separately excited ★ *Circle No.* 707
British Central Elec.
Brush Electrical
Evershed & Vignoles
Klaxon
Laurence Scott
Newton Bros. (Derby)
Vactric Control Equipment
Western Mfg. Reading

MOTORS, electric, d.c. servo—split-field ★ *Circle No.* 708
British Central Elec.
Brush Electrical
Evershed & Vignoles
Kelvin & Hughes
Klaxon
Laurence Scott
Muirhead
Newton Brothers (Derby)
Parvalux
Plessey Co.
Servo & Electronic Sales
Small Electric Motors
Vactric Control Equipment
Walter Jones
Western Mfg. Reading

MOTORS, electric, d.c. servo—torque ★ *Circle No.* 709
British Central Elec.
Brush Electrical
Klaxon
Laurence Scott
Newton Brothers (Derby)
Short Bros. & Harland
Siemens Edison Swan
Walter Jones
Woden Transformer

MOTORS, electric f.h.p. ★ *Circle No.* 710
A.E.I.
Amphenol (G.B.)
British Central Elec.
British Universal E.M.E.
Brook Motors
Brush Electrical
Citenco Ltd.
Crompton Parkinson
Croydon Engineering
Devon Instruments
Drayton Regulator
Elliott Nucleonics
English Electric
Evershed & Vignoles
Fractional H.P. Motors
Fred Ferraris
Fuel Efficiency
G.E.C.
George Kent
Griffin & George
Jeary Electrical
Joyce Electrical
Kelvin & Hughes
Klaxon
Laurence Scott
Law & Plumtree
Louis Newmark
Majestic Electric
Mortley Sprague
Mycalex
Nelco
Newman Industries
Oliver Pell
Parvalux
Plessey Co.
Pullin, R. B.
Simmons Electrical Winding
Small Electric Motors
Stewart Aero Supply
Telecommunication Inst.
Welmec Corporation
Western Mfg., Reading
Whitetrade

MOTORS, hydraulic servo (rotary output). See also **Actuators, hydraulic** ★ *Circle No.* 711
Andrew Fraser
Boulton Paul Aircraft
Chamberlain Industries
Dowty Hydraulic Units
H.M.L.
Hobson, H. M.
Integral
Joseph Lucas
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Lockheed Precision Products
Muirhead
Plessey Co.
Reavell-Fahie
Short Bros. & Harland
Sperry Gyroscope
Stewart Aero Supply
Vickers
Woden Transformer

MOTORS, pneumatic servo (rotary output). See also **Actuators, pneumatic** ★ *Circle No.* 712
Atlas Copco (G.B.)
Fred Ferraris
Globé Pneumatic Eng.
Holman Bros.
Plessey Co.
Stewart Aero Supply

MOULDINGS ★ *Circle No.* 713
Anglo American V.F.
British Sarozal
Dowty Seals
Dunlop Rubber
Electrothermal Eng.
Epsylon Industries
Ernest Turner
George Goodman
Hall & Hall
Hawley Products
Hellermann
Joyce Electrical
Lion Electronic Develop.
M.B. Metals
Measurement Limited
Mycalex
Neosid
Permali
Peto Scott
Precision Rubbers
Siemens Edison Swan

NEPHELOMETERS. Included under **Photometric instruments**

NEUTRON FLUX METERS ★ *Circle No.* 714
Ekco Electronics
Ericsson Telephones
Research & Control Inst.

ORIFICE PLATES. See **Flowmeters**

OSCILLATORS, electronic—a.f. ★ *Circle No.* 715
A.C.M. Electronics
Advance Components
Airmec
Allied Electronics
Aveley Electric
British Physical Labs.
Bruce Peebles
Cawkell
Claude Lyons
Cole (Overseas), R. H.
Cossor Instruments
Craven Electronics
Dawe Instruments
Farnell Instruments
Furzehill Labs.
Goodmans Industries
Hatfield Instruments
Holiday & Hemmerdinger
Kasama Electronics
Lancashire Dynamo Elect.
Leland Instruments
Marconi Instruments
Metrix Instruments
Miles-Hivolt
Muirhead
Nash & Thompson
Newman Industries
Pye, W. G.
Rank Cintel
Research & Control Inst.
S.E. Laboratories

★ For further details circle on card facing page 214

- Solartron
- S.S. Electronics
- Taylor Electrical
- Tinsley, H.
- Venner Electronics
- Wayne Kerr Labs.
- Winston Electronics

OSCILLATORS, electronic—beat frequency ★ *Circle No.* 716

- Aveley Electric
- B. & K. Labs.
- British Physical Labs.
- Brown, S. G.
- Bruce Peebles
- Claude Lyons
- Cole (Overseas), R. H.
- Cossor Instruments
- Craven Instruments
- Farnell Instruments
- Leland Instruments
- Marconi Instruments
- Research & Control Inst.

OSCILLATORS, electronic—microwave ★ *Circle No.* 717

- Aveley Electric
- B. & K. Labs.
- Bradley, G. & E.
- Bruce Peebles
- Cole (Overseas), R. H.
- Decca Radar
- Farnell Instruments
- Ferranti
- Leland Instruments
- Marconi Instruments
- Research & Control Inst.
- Sanders (Electronics), W. H.
- Telecommunication Inst.
- Wayne Kerr Labs.
- Winston Electronics

OSCILLATORS, electronic—ultrasonic ★ *Circle No.* 718

- Advance Components
- Aveley Electric
- British Sarozal
- Bruce Peebles
- Craven Electronics
- Farnell Instruments
- Furzehill Instruments
- Glass Developments
- Kelvin & Hughes
- Marconi Instruments
- Wayne Kerr Labs.

OSCILLATORS, electronic—very low frequency ★ *Circle No.* 719

- Advance Components
- Airmec
- Armstrong Whitworth Equip.
- Aveley Electric
- Bruce Peebles
- Claude Lyons
- Craven Electronics
- Dawe Instruments
- Dobbie McInnes
- Farnell Instruments
- Feedback
- Leland Instruments
- Louis Newmark
- Metrix Instruments
- Muirhead
- Nash & Thompson
- Pye, W. G.
- Research & Control Inst
- Servomex Controls
- Short Bros. & Harland
- Siemens Edison Swan
- Solartron
- S. S. Electronics
- Taylor Electrical

OSCILLOSCOPES, cathode-ray—calibrated ★ *Circle No.* 720

- Aerocontacts
- Airmec
- Allied Electronics
- Aveley Electric
- British Central Elec.
- Bruce Peebles
- Cawkell
- Cossor Instruments
- Craven Electronics
- EMI Electronics
- Furzehill Labs.
- Farnell Instruments
- Holliday & Hemmerdinger
- Kasama Electronics
- Leland Instruments
- Louis Newmark
- Marconi Instruments
- Mullard Equipment
- Plessey Co.
- R.C.A. (G.B.)
- Research & Control Inst.
- Sanders (Electronics), W. H.
- Sciaky Electric Welding
- Solartron
- Southern Instruments
- S.S. Electronics
- Telequipment

OSCILLOSCOPES, cathode-ray—non-calibrated ★ *Circle No.* 721

- A.C.M. Electronics
- A.E.I.
- Aerocontacts
- Airmec
- Allied Electronics
- British Central Elec.
- Bruce Peebles
- Cossor Instruments
- Craven Electronics
- Farnell Instruments
- Leland Instruments
- Marconi Instruments
- Mullard Equipment
- Plessey Nucleonics
- Rank Cintel
- Research & Control Inst.
- Sciaky Electric Welding
- Solartron
- S.S. Electronics
- Taylor Electrical

OSCILLOSCOPES, cathode-ray—storage ★ *Circle No.* 722

- British Central Elec.
- Bruce Peebles
- Cawkell
- Cossor Instruments
- Ferranti
- Leland Instruments
- Mullard Equipment
- Sciaky Electric Welding
- Solartron

OSCILLOGRAPHS. See **Recorders**

OXYGEN ANALYSERS. Included under **Analytical instruments**

PHASE-ANGLE INDICATORS ★ *Circle No.* 723

- Armstrong Whitworth Equip.
- Aveley Electric
- English Electric
- G.E.C.
- Kandem Electrical
- Lancashire Dynamo Elect.
- Louis Newmark
- Muirhead
- Salford Elec. Instruments
- Saunders-Roe
- Sciaky Electric Welding
- Short Bros. & Harland
- White & Riches

pH CONTROLLERS. See also **Controllers**

pH CONTROLLERS — electric output ★ *Circle No.* 724

- Bailey Meters & Control
- British Arca Regulators
- Bristol Inst.
- Cambridge Instruments
- Doran Instrument
- Electroflo Meters
- Elliott Brothers
- Ether
- Fielden Electronics
- Foxboro-Yoxall
- George Kent
- Honeywell Controls
- Integra Leeds
- Kandem Electrical
- Langham Thompson, J.
- Lock, A. M.
- Pye, W. G.
- Research & Control Inst.
- Wykeham, W.

pH CONTROLLERS—pneumatic output ★ *Circle No.* 725

- Bristol Inst.
- British Arca Regulators
- Cambridge Instrument
- Electroflo Meters
- Elliott Brothers
- Elliott Nucleonics
- Fielden Electronics
- Foxboro-Yoxall
- George Kent
- Honeywell Controls
- Kandem Electrical
- Wykeham, W.

pH INDICATORS ★ *Circle No.* 726

- Analytical Measurements
- Bailey Meters & Control
- B. & K. Labs.
- Bristol Inst.
- Cambridge Instrument
- Doran Instrument
- Elliott Brothers
- Griffin & George
- G.E.C.
- George Kent
- Kandem Electrical
- Langham Thompson, J.
- Marconi Instruments
- Pye, W. G.
- Research & Control Inst.
- Reynolds & Branson
- Wykeham, W.

PHOTOCELLS. See **Radiation detectors, photocells**

PHOTOELECTRIC CONTROLLERS. See also **Controllers, electric** ★ *Circle No.* 727

- Airmec
- A.E.I.
- Allied Electronics
- British Central Elec.
- Bruce Peebles
- Craven Electronics
- Digital Engineering
- Elcontrol
- Electro Methods
- Electronic Switchgear
- Electrotechnic
- Ericsson Telephones
- Ether
- Farnell Instruments
- G.E.C.
- H. & B. Precision Eng.
- Headland Eng. Developments
- John Thompson Instrument
- Kelvin & Hughes
- Lancashire Dynamo Elect.
- Lintronic
- Lock, A. M.
- Londex
- Newman Industries
- Parmeko
- Photoelectronics (M.O.M.)
- Pillinger, G. C.
- Radiovisor Parent
- Rheostatic Co.
- Sanders (Electronics), W. H.
- Stonebridge Electrical
- Teddington Ind. Equip.
- Tyer
- Venner Electronics

PHOTOMETRIC INSTRUMENTS, continuous reading. See also **Spectrometers and spectrophotometers** ★ *Circle No.* 728

- Baldwin Industrial Controls
- Evans Electroselenium
- Gallenkamp, A.
- Griffin & George
- Joyce Loebel
- Lancashire Dynamo Elect.
- Radiovisor Parent
- Sargrove Electronics
- Southern Instruments

PLUGS AND SOCKETS—coaxial ★ *Circle No.* 729

- Aerocontacts
- Aircraft Marine Prod.
- Amphenol (G.B.)
- Aveley Electric
- Belling & Lee
- B.I.C.C.
- British Central Elec.
- British Sarozal
- Claude Lyons
- Colvern
- Farnell Instruments
- Films & Equipments
- Hellermann
- Holliday & Hemmerdinger
- I.E.C.-Sieger
- M.B. Metals
- Magnet Devices
- Marconi, W. T.
- Plessey Co.
- Radiospares
- R.C.A. (G.B.)
- Ryecroft Electric
- Sealectro Corporation
- Siemens Edison Swan
- Stewart Aero Supply
- Vidor Batteries
- Wilkinson (Croydon), L.

PLUGS AND SOCKETS—single and multiway ★ *Circle No.* 730

- Aerocontacts
- Aircraft Marine Prod.
- Amphenol (G.B.)
- Aveley Electric
- Belling & Lee
- British Central Elec.
- British Sarozal
- Bulgin, A. F.
- Continental Connector
- Electro Methods
- Electronic Components
- Farnell Instruments
- Films & Equipments
- Hellermann
- Holliday & Hemmerdinger
- London Instrument Co.
- Magnet Devices
- M.B. Metals
- N.S.F.
- Plessey Co.
- Radiospares
- R.C.A. (G.B.)
- Reosound Engineering
- Sealectro Corporation
- Siemens Edison Swan
- Simplex Electric
- Spear Engineering
- Stewart Aero Supply
- Thorn Electrical Industries
- Vidor Batteries
- Wilkinson (Croydon), L.

PLUGS AND SOCKETS—sub-miniature ★ *Circle No.* 731

- Aerocontacts
- Aircraft Marine Prod.
- Amphenol (G.B.)
- Ardente Acoustic Lab.
- Belling & Lee
- Bulgin, A. F.
- Continental Connector
- Electro Methods
- Farnell Instruments
- Films & Equipments
- Hellermann
- I.E.C.-Sieger
- M.B. Metals
- Multitune Electric Co.
- N.S.F.
- Plessey Co.
- Radiospares
- R.C.A. (G.B.)
- Sealectro Corporation
- Spear Engineering
- Stewart Aero Supply
- Thorn Electrical Ind.
- Vidor Batteries

PLUGS AND SOCKETS—wired ★ *Circle No.* 732

- Aerocontacts
- Aircraft Marine Prod.
- Amphenol (G.B.)
- Continental Connector
- Hellermann
- Lion Electronic Develop.
- M.B. Metals
- Plessey Company
- R.C.A. (G.B.)
- Siemens Edison Swan
- Stewart Aero Supply

POLAROGRAPHS ★ *Circle No.* 733

- Baird & Tatlock
- B. & K. Labs.
- Cambridge Instrument
- Evershed & Vignoles
- Integra Leeds
- Mervyn Instruments
- Nash & Thompson
- Southern Instruments

POSITION TRANSDUCERS. See **Displacement transducers**

POTENTIOMETERS, precision servo—linear ★ *Circle No.* 734

- Air Trainers Link
- Beckman Instruments
- Bristol Inst.
- British Ele. Resistance Co.
- British Sarozal
- Brown, S. G.
- Colvern
- Electronic Associates
- Elliott Brothers
- Elliott Nucleonics
- Farnell Instruments
- Ferranti
- Fox, P. X.
- General Controls
- Graseby Instruments
- Honeywell Controls
- Integra Leeds
- Kynmore Eng.
- Painton & Co.
- Plessey Co.
- Radiospares
- Reliance Mfg. Co.
- Salford Elec. Instruments
- Sperry Gyroscope
- Stewart Aero Supply
- Winston Electronics

POTENTIOMETERS, precision servo—non-linear ★ *Circle No.* 735

- Air Trainers Link
- Beckman Instruments
- British Elec. Resistance Co.
- British Sarozal
- Brown, S. G.
- Colvern
- Farnell Instruments
- Fox, P. X.
- General Controls
- Kelvin & Hughes
- Kynmore Eng.
- Plessey Co.
- Radiospares
- Reliance Mfg. Co.
- Salford Elec. Instruments
- Sperry Gyroscope
- Stewart Aero Supply
- Winston Electronics

POTENTIOMETERS, precision servo—miniature ★ *Circle No.* 736

- Ardente Acoustic Lab.
- Beckman Instruments
- British Elec. Resistance Co.
- Brown, S. G.
- Colvern
- Farnell Instruments
- Ferranti
- Fox, P. X.
- General Controls
- Langham Thompson, J.
- Mervyn Instruments
- Painton & Co.
- Plessey Co.
- Radiospares
- Reliance Mfg. Co.
- Salford Elec. Instruments
- Stewart Aero Supply
- Tinsley, H.
- Winston Electronics

POWER PACKS—a.c. ★ *Circle No.* 737

- A.C.M. Electronics
- Advance Components
- Airtech
- Aveley Electric
- Allied Electronics
- Automation Consultants
- British Central Elec.
- British Sarozal
- Brown, S. G.
- Bruce Peebles
- Bryan Savage
- Decca Radar
- Electrotechnic Ltd.
- Farnell Instruments
- George Kent
- Hatfield Instruments
- Hirst Electronics
- Kasama Electronics
- Kendall & Mousley
- Lancashire Dynamo Elect.
- Magneta Time Co.
- Marconi, W. T.
- Metrix Instruments
- Miles-Hivolt
- Newport Instruments
- Parmeko
- Plessey Co.
- Research & Control Inst.
- Sanders (Electronics), W. H.
- Servomex Controls
- Siemens Edison Swan
- South London Elec. Equip.
- Swartwout
- Telemechanics
- Transformer & Electric
- Venner Electronics
- Vernons Industries
- Woden Transformer

POWER PACKS—d.c. ★ *Circle No.* 738

- A.C.M. Electronics
- Advance Components
- Airtech
- Allied Electronics
- A.P.T. Electronic Indust.
- Armstrong Whitworth Equip.
- Automa Engineering
- Automation Consultants
- Aveley Electric
- Air Trainers Link
- Boulton Paul Aircraft
- British Central Elec.
- Bruce Peebles
- Cawkell
- Claude Lyons
- Clive Courtney
- Cossor Instruments
- Dynatron Radio
- Ekco Electronics
- Electrotechnic
- Ericsson Telephones
- Farnell Instruments
- Feedback
- George Kent
- Haddon Transformers
- Hatfield Instruments
- Hirst Electronics
- Kasama Electronics
- Kelvin & Hughes
- Kendall & Mousley
- Labgear
- Lancashire Dynamo Elect.
- Lintronic
- Marconi Instruments
- Marconi, W. T.
- Metrix Instruments
- Miles-Hivolt
- Nash & Thompson
- Newport Instruments
- Parmeko
- Plessey Co.
- Pye, W. G.
- Research & Control Inst.
- Robinson & Partners, F. C.
- Sanders (Electronics), W. H.
- Saunders-Roe
- Servomex Controls
- Smith Jacking Systems
- Solartron
- South London Elec. Equip.
- S.S. Electronics
- Stanley & Co., W. F.
- Telecommunication
- Telemechanics
- Thorn Electrical Ind.
- Transformer & Electrical
- Vernons Industries
- White & Riches
- Woden Transformer

POWER PACKS—hydraulic ★ *Circle No.* 739

- Dowty Equipment
- Dowty Hydraulic Units
- H.M.L.
- Hydraulics & Pneumatics
- Integral
- Joseph Lucas
- Joseph Lucas (H. & C.)
- Keelavite Hydraulics
- Lockheed Precision Products
- Marley, W. H.
- Oswalds & Ridgway
- Plessey Co.
- Pratt Precision
- Smiths Jacking Systems
- Spenborough Engineering
- Stein Atkinson

POWER PACKS—pneumatic ★ *Circle No.* 740

- Air Pumps
- Atlas Copco (G.B.)
- Alfred Bullows
- Consolidated Pneumatic
- Dawson McDonald
- Electroflo Meters
- H.E.C.
- Holman Bros.
- Hydraulics & Pneumatics
- Hymatic Engineering
- Levis
- Reavell-Fahie

PRESSURE CONTROLLERS. See also **Controllers**

PRESSURE CONTROLLERS—electric output ★ *Circle No.* 741

- Appleby & Ireland
- Bailey Meters & Control
- Black Automatic Controls
- Bristol Inst.
- Cambridge Instrument
- Craven Electronics
- Danfoss
- Delta Technical Services
- Dewrance
- Drayton Regulator
- Electroflo Meters

★ *For further details circle on card facing page 214*

Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Fielden Electronics
Foxboro-Yoxall
George Kent
Honeywell Controls
Integra Leeds
James Gordon
John Thompson Instrument
Kandem Electrical
Kelvin & Hughes
K.D.G. Instruments
Lancashire Dynamo Elect.
Lintronic
Londex
Normalair
Rheostatic Co.
Sauter Controls
Swartwout
Teddington Ind. Equip.
Thermal Control Company

PRESSURE CONTROLLERS— pneumatic output
★ *Circle No. 742*
Aeraspray Associated
Bailey Meters & Control
Benton & Stone
British Arca Regulators
Bristol Inst.
Cheltenham Autocontrols
Crosby Valve & Eng.
Delta Technical Services
Dunlop Rubber
Drayton Regulator
Elec. Steam & Mining
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Fielden Electronics
Fisher Governor
Foxboro-Yoxall
George Kent
Hobson, H. M.
Honeywell Controls
Hymatic Engineering
James Gordon
Kandem Electrical
K.D.G. Instruments
Martonair
Negretti & Zambra
Norgren, C. A.
Normalair
Reavell-Fahie
Samson Controls
Sauter Controls
S.E. Laboratories
Stuart Davis
Sunvic Controls
Taylor Controls
Teddington Ind. Equip.
Volspray
Westinghouse Brake

PRESSURE INDICATORS— pressure-sensitive wire
★ *Circle No. 743*
Cossor Instruments
Lintronic
Solartron

PRESSURE INDICATORS— temperature-resistance effect
★ *Circle No. 744*
Smith & Sons (England), S.

PRESSURE INDICATORS
Those which follow employ mechanical measuring elements

PRESSURE INDICATORS— bellows
★ *Circle No. 745*
Appleby & Ireland
Bamford, F.
Black Automatic Controls
Bristol Inst.
Cheltenham Autocontrols
Delta Technical Services
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Foxboro-Yoxall
Fuel Efficiency
George Kent
Graseby Instruments
Honeywell Controls
James Gordon
John Thompson Instrument
Kelvin & Hughes
Leybold Vacuum Sales
Payne & Griffiths
Sangamo Weston
Short & Mason
Sunvic Controls
Sydney Smith
Taylor Controls
Teddington Ind. Equip.
Vernon Instrument

PRESSURE INDICATORS— bourdon tube
★ *Circle No. 746*
Appleby & Ireland
Bailey & Mackey
Black Automatic Controls
Bristol Inst.
British Steam Specialties
Budenberg Gauge
Delta Technical Services
David Harcourt
Dewrance
Elliott Brothers
Electroflo Meters
Elliott Nucleonics
Evershed & Vignoles
Fielden Electronics
Foxboro-Yoxall
Fuel Efficiency
George Kent
Graseby Instruments
Honeywell Controls
Hunt & Mitton
Kandem Electrical
Kelvin & Hughes
K.D.G. Instruments
Leybold Vacuum Sales
Nottingham Thermometer
Payne & Griffiths
Salford Elec. Instruments
Smith & Sons (England), S.
Smiths Industrial Inst.
Stanley, W. F.
Sunvic Controls
Sydney Smith
Taylor Controls
Teddington Ind. Equip.
Wallace & Tiernan

PRESSURE INDICATORS— diaphragm, metallic
★ *Circle No. 747*
Appleby & Ireland
Aeraspray Associated
Armstrong Whitworth Equip.
Bailey & Mackey
Black Automatic Controls
Bristol Inst.
British Steam Specialties
Budenberg Gauge
Cheltenham Autocontrols
David Harcourt
Delta Technical Services
Electro-Mechanical Systems
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Fielden Electronics
Firth Cleveland Instruments
Foxboro-Yoxall
James Gordon
Kandem Electrical
K.D.G. Instruments
Kelvin & Hughes
Leybold Vacuum Sales
M.B. Metals
Mechanism
Nottingham Thermometer
Payne & Griffiths
Salford Elec. Instruments
Saunders-Roe
S.E. Laboratories
Sigma Inst.
Short & Mason
Smiths Industrial Inst.
Taylor Controls
Thermalcon Co.
Stanley, W. F.
Sydney Smith

PRESSURE INDICATORS— diaphragm, non-metallic
★ *Circle No. 748*
Appleby & Ireland
Bailey & Mackey
Black Automatic Controls
Bristol Inst.
Cheltenham Autocontrols
Delta Technical Services
Drayton Regulator
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
George Kent
K.D.G. Instruments
Precision Rubbers
Taylor Controls

PRESSURE INDICATORS— liquid-sealed bell
★ *Circle No. 749*
Delta Technical Services
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Foxboro-Yoxall
Honeywell Controls
Sigma Inst.
Taylor Controls
Walker Crosweller

PRESSURE INDICATORS— McLeod gauge
★ *Circle No. 750*
Edwards High Vacuum
Leybold Vacuum Sales
Pulsometer Eng.

PRESSURE INDICATORS— ring-balance manometer
★ *Circle No. 751*
Electroflo Meters
George Kent

PRESSURE INDICATORS— U-tube manometer
★ *Circle No. 752*
Airflow Developments
Bristol Inst.
Bryans Aeroequipment
Combustion Instruments
Delta Technical Services
Edwards High Vacuum
Electrical Thermometer
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Foxboro-Yoxall
George Kent
Hobson, H. M.
John Thompson Instrument
Kelvin & Hughes
Leybold Vacuum Sales
Nottingham Thermometer
Stanley, W. F.
Sydney Smith
Taylor Controls
Vernon Instrument
Walker Crosweller

PRINTED CIRCUITS, design and production facilities
★ *Circle No. 753*
A.E.I.
Armstrong Whitworth Equip.
Bribond
Bruce Peebles
Continental Connector
Cossor Instruments
Ericsson Telephones
Ferranti
G.E.C.
Louis Newmark
Millett Levens
Peto Scott
Plessey Co.
Printed Circuits
Rank Cintel
Rank Precision Industries
R.C.A. (G.B.)
Sealey Engineering
Siemens Edison Swan
Technograph
Telecommunication Inst.
Vidor Batteries

PRINTERS— on-line
★ *Circle No. 754*
Creed & Company
Electronic Associates
I.C.T.
Lindars Automation
Radiatron
Rank Precision Industries
Trumeter
Venner Electronics

PRINTERS— off-line
★ *Circle No. 755*
Creed & Company
Electronic Associates
Hilger & Watts
I.C.T.
Rank Precision Industries
Saunders-Roe
Underwood

PROGRAMME CONTROLLERS. See **Controllers, programme**

PULSE HEIGHT ANALYSERS
★ *Circle No. 756*
Dynatron Radio
Ekco Electronics
Isotope Developments
Lion Electronic Developments
Marshall of Cambridge
Mullard Equipment
Nuclear Enterprises
Panax Equipment
Plessey Nucleonics
Research & Control Inst.
Sunvic Controls

PUMPS, HYDRAULIC— positive-displacement, fixed delivery
★ *Circle No. 757*
Andrew Fraser
Bailey, Sir W. H.
B. & P. Swift
Chamberlain Industries
Dowty Fuel Systems
Dowty Hydraulic Units
Electro-Hydraulics
Fawcett Preston
Hamworthy Eng.
H.M.L.
Hobson, H. M.
Holman Bros.
Hydraulics & Pneumatics
Integral
James W. Carr
Joseph Lucas
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Lockheed Precision Products
Marley, W. H.
Measurement Ltd.
Oswalds & Ridgway
Plessey Co.
Pratt Precision
Plenty & Son
Power Jacks
Pulsometer Eng.
Reavell-Fahie
Smith & Sons (England), S.
Smith Jacking Systems Ltd.
Spenborough Engineering
Sperry Gyroscope
Stein Atkinson
Tangyes
Towler Bros.
Varley, F. M. C.
Vickers
Wallace & Tiernan
Worthington Simpson
Vickers-Armstrong

PUMPS, HYDRAULIC— positive-displacement, variable delivery
★ *Circle No. 758*
Andrew Fraser
Boulton Paul Aircraft
Dowty Fuel Systems
Dowty Hydraulic Units
Electro-Hydraulics
H.M.L.
Hobson, H. M.
Holman Bros.
Hydraulics & Pneumatics
Hamworthy Eng.
Integral
Joseph Lucas
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Kontak Manufacturing
Lockheed Precision Products
Measurement Limited
Plessey Co.
Plenty & Son
Pulsometer Eng.
Smith & Sons (England), S.
Sperry Gyroscope
Tangyes
Varley, F. M. C.
Vickers
Vickers-Armstrong
Wallace & Tiernan
Worthington Simpson

PUMPS, HYDRAULIC— rotodynamic
★ *Circle No. 759*
Electro-Hydraulics
Girdlestone Pumps
H.M.L.
Hobson, H. M.
Lockheed Precision Products
Smith & Sons (England), S.
Spenborough Engineering

PUMPS, METERING
★ *Circle No. 760*
Distillers
Hobson, H. M.
H.M.L.
Joseph Lucas
Joseph Lucas (H & C)
Kontak Manufacturing
Metering Pumps
Plenty & Son
Plessey Co.
Wallace & Tiernan

PUNCHED CARD EQUIPMENT
★ *Circle No. 761*
Bray, E. N.
Fuel Efficiency
Gresham Developments
IBM United Kingdom
I.C.T.

PUNCHED CARD AUXILIARY EQUIPMENT
★ *Circle No. 762*
Punched Card Accessories

PUNCHED TAPE EQUIPMENT
★ *Circle No. 763*
Creed & Company
Digital Engineering
Ericsson Telephones
I.C.T.
Lancashire Dynamo Elect.
R.C.A. (G.B.)
Underwood
Welmec Corporation

PYROMETERS— optical
★ *Circle No. 764*
Cambridge Instruments
Elliott Brothers
Elliott Nucleonics
Ether
Evershed & Vignoles
Foster Instrument
Griffin & George
Honeywell Controls
Integra Leeds
Kandem Electrical
Land Pyrometers
Plessey Co.
Radiovisor Parent

PYROMETERS— thermocouple
★ *Circle No. 765*
Bailey Meters & Control
British Sarozal
Bush, Beach, Segner Bayley
Cambridge Instrument
Coley Thermometers
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Ether
Evershed & Vignoles
Fielden Electronics
Foster Instrument
Fuel Efficiency
Griffin & George
Harvey Electronics
Headland Eng. Developments
Honeywell Controls
Integra Leeds
Industrial Pyrometer
Kandem Electrical
James Gordon
John Thompson Instrument
Kelvin & Hughes
Land Pyrometers
Negretti & Zambra
Page Engineering
Sangamo Weston
Sifam Electrical Instruments
Taylor Controls
West Instrument
White Electrical Instruments

RACKS, MOUNTING
★ *Circle No. 766*
A.C.M. Electronics
Alfred Imhof
British Sarozal
Bruce Peebles
Datum Metal Products
Digital Engineering
Dynatron Radio
Ericsson Telephones
George Kent
Hallam Sleigh & Cheston
Lund Bros.
Rank Cintel
Reosound Engineering
Telecommunication Inst.
Wilkinson (Croydon), L.

RADIATION DETECTORS, nucleonic. See also **Counters (scintillation and geiger)**
★ *Circle No. 767*
Airmec
Avo
Baldwin Industrial Controls
Bruce Peebles
Dynatron Radio
Ekco Electronics
Elliott Brothers
Ericsson Telephones
Fleming Radio
General Radiological
Hendrey Relays
Isotope Developments
Joseph Lucas
Labgear
Mervyn Instruments
Nuclear Enterprises
Panax Equipment
Plessey Nucleonics
Radiatron
Research & Control Inst.
20th. Century Electronics
Vidor Batteries

RADIATION DETECTORS, infra-red—bolometers
★ *Circle No. 768*
Plessey Co.
20th. Century Electronics

RADIATION DETECTORS, infra-red—pneumatic
★ *Circle No. 769*
Unicam Instruments

RADIATION DETECTORS, infra-red—semi-conductor
★ *Circle No. 770*
Bruce Peebles
Cole (Overseas), R. H.
Hilger & Watts
Mullard
Plessey Co.
Standard Telephones

RADIATION DETECTORS, infra-red—thermocouple
★ *Circle No. 771*
Elliott Brothers
Hilger & Watts
Honeywell Controls
Integra Leeds
Kandem Electrical

RADIATION DETECTORS, infra-red—other than the preceding types
★ *Circle No. 772*
Bruce Peebles
Cathodeon
Radiovisor Parent
Technical Ceramics
20th. Century Electronics

RADIATION DETECTORS, photocell—photoconductive
★ *Circle No. 773*
Bruce Peebles
Cathodeon
Cole (Overseas), R. H.
Ericsson Telephones
Hilger & Watts
Kandem Electrical
Mullard
Mervyn Instruments
Radiovisor Parent
Rank Cintel
R.C.A. (G.B.)
Texas Instruments

RADIATION DETECTORS, photocell—photoemissive
★ *Circle No. 774*
Baldwin Industrial Controls
Bruce Peebles
Cathodeon
Cole (Overseas), R. H.
EMI Electronics
Mullard
Radiovisor Parent
Rank Cintel
20th. Century Electronics

RADIATION DETECTORS, photocell—phototransistor
★ *Circle No. 775*
Bruce Peebles
Hilger & Watts
Mullard
Rank Cintel
R.C.A. (G.B.)
Timothy Eaton

RADIATION DETECTORS, photocell—photovoltaic
★ *Circle No. 776*
Bruce Peebles
Ferranti

RADIOACTIVE SOURCES. See **Isotopes**

RAILWAY SIGNALLING EQUIPMENT
★ *Circle No. 777*
Bruce Peebles
Brush Electrical
Engel & Gibbs
G.E.C.
Miles-Hivolt
M.L. Aviation Company
Page Engineering
Plessey Co.
Siemens Edison Swan
Standard Telephones
Telecommunication Inst.
Thorn Electrical Ind.
Westinghouse Brake

★ For further details circle on card facing page 214

RATEMETERS. See Counters

READING MACHINES
★ *Circle No.* 778
Solartron

READ-OUT EQUIPMENT—magnetic tape
★ *Circle No.* 779
Ampex Electronics
Decca Radar
Epsylon Industries
Gresham Developments
I.C.T.
Newman Industries
R.C.A. (G.B.)
Royston Instruments
Standard Telephones
Thermionic Products

READ-OUT EQUIPMENT—paper tape
★ *Circle No.* 780
Creed & Company
Ericsson Telephones
Leland Instruments
Radiatron
R.C.A. (G.B.)
Servo Units
Standard Telephones
Underwood

RECORDERS — galvanometer, direct writing, spark or method other than pen
★ *Circle No.* 781
Bailey Meters & Control
Dobbie McInnes
Electroflo Meters
Evershed & Vignoles
Elliott Brothers
Ether
Films & Equipments
Fuel Efficiency
Hendrey Relays
I.E.C.-Sieger
John Thompson Instrument
Kandem Electrical
Kelvin & Hughes
Metrix Instruments
New Electronic Products
S.E. Laboratories
Servis Recorders
Sierex
Sifam Electrical Instruments
Welmec Corporation

RECORDERS — galvanometer direct writing, pen
★ *Circle No.* 782
Bailey Meters & Control
British Sarozal
Cambridge Instrument
Dobbie McInnes
Electronic Associates
Elliott Brothers
Elliott Nucleonics
Everett Edgcumbe
Evershed & Vignoles
Fuel Efficiency
Fielden Electronics
I.E.C.-Sieger
Integra Leeds
James Gordon
Kandem Electrical
Kelvin & Hughes
Langham Thompson, J.
Metrix Instruments
Record Elec.
Research & Control Inst.
Welmec Corporation

RECORDERS — galvanometer light beam, photographic recording
★ *Circle No.* 783
British Sarozal
Cambridge Instrument
Electro-Mechanical Systems
Ernest Turner
Evershed & Vignoles
Films & Equipments
I.E.C.-Sieger
Kandem Electrical
New Electronic Products
Savage & Parsons
S.E. Laboratories
Southern Instruments
Tinsley, H.

RECORDERS—miniature pneumatic (scale smaller than 9 in.)
★ *Circle No.* 784
Bristol Inst.
Electroflo Meters
Elliott Borthers
Elliott Nucleonics
Foxboro-Yoxall
Honeywell Controls
Kandem Electrical
Sunvic Controls
Taylor Controls
Vernon Instrument

RECORDERS—miniature electronic (scale smaller than 9 in.)
★ *Circle No.* 785
Bailey Meters & Control
British Sarozal
Cambridge Instrument
Dewrance
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Ether
Evershed & Vignoles
Fielden Electronics
Firth Cleveland Instruments
James Gordon
Kandem Electrical
Mervyn Instruments
Metrix Instruments
Rank Cintel
Research & Control Inst.
Swartwout
Taylor Controls

RECORDERS—operations
★ *Circle No.* 786
Bailey Meters & Control
Elliott Brothers
Everett Edgcumbe
Evershed & Vignoles
Foxboro-Yoxall
Hasler Telegraph Works
Lancashire Dynamo Elect.
Robinson & Partners, F. C.

RECORDERS — self-balancing potentiometric recorders, circular chart
★ *Circle No.* 787
Bailey Meters & Control
Bristol Inst.
Craven Electronics
Electroflo Meters
Electronic Switchgear
Elliott Brothers
Elliott Nucleonics
Foster Instrument
Foxboro-Yoxall
Fielden Electronics
Fuel Efficiency
George Kent
Honeywell Controls
I.E.C.-Sieger
Integra Leeds
James Gordon
John Thompson Instrument
Lancashire Dynamo Elect.
Parkinson Cowan Instruments

RECORDERS — self-balancing potentiometric recorders, strip chart
★ *Circle No.* 788
Aveley Electric
Bailey Meters & Control
Cambridge Instrument
Electroflo Meters
Electronic Switchgear
Elliott Brothers
Elliott Nucleonics
Ether
Evershed & Vignoles
Firth Cleveland Inst.
Foster Instrument
Fuel Efficiency
George Kent
Headland Eng. Developments
Honeywell Controls
I.E.C.-Sieger
Industrial Pyrometer
Integra Leeds
James Gordon
Kandem Electrical
Lancashire Dynamo Elect.
Parkinson Cowan Instruments
Research & Control Inst.
Southern Instruments
Sunvic Controls

RECORDERS—special purpose
★ *Circle No.* 789
British Rototherm
British Sarozal
Cambridge Instrument
Dawe Instruments
Digital Engineering
Dobbie McInnes
Electro Methods
Epsylon Industries
Lancashire Dynamo Elect.
Marconi W. T.
Rank Precision Industries
Research & Control Inst.
Sifam Electrical Instruments
Sigma Inst.
Smiths Industrial Instruments
Thomas Mercer (Air Gauges)
Walker Crosweller
White & Riches

RECORDERS—*X-Y*
★ *Circle No.* 790
Air Trainers Link
Benson-Lehner (G.B.)
Bryans Aeroequipment
Dobbie McInnes
Electronic Associates
Honeywell Controls
Integra Leeds
I.E.C.-Sieger
Lancashire Dynamo Elect.
Louis Newmark
Research & Control Inst.
Scientific Furnishings
S.E. Laboratories
White & Riches

RECTIFIERS, electronic. See **Valves, electronic—rectifying**

RECTIFIERS, metal
★ *Circle No.* 791
British Central Elec.
Cole (Overseas), R. H.
Fuller Electric
G.E.C.
Hackbridge & Hewittic
Hirst Electronic
Holiday & Hemmerdinger
Lancashire Dynamo Nevelin
Langham Thompson, J.
Miles-Hivolt
Radiospares
Salford Elec. Instruments
Standard Telephones
Stewart Aero Supply
Westinghouse Brake
Wilkinson (Croydon), L.

RECTIFIERS, mercury arc
★ *Circle No.* 792
A.E.I.
British Central Elec.
Bruce Peebles
English Electric
Fuller Electric
G.E.C.
Hackbridge & Hewittic
Hirst Electronics
Lancashire Dynamo Nevelin
Miles-Hivolt

RECTIFIERS, semi-conductor
★ *Circle No.* 793
A.E.I.
Brush Crystal
Cole (Overseas), R. H.
English Electric
English Electric Valve
Ferranti
G.E.C.
Holiday & Hemmerdinger
Hackbridge & Hewittic
Joseph Lucas
Lancashire Dynamo Nevelin
Mullard
Plessey Co.
R.C.A. (G.B.)
Siemens Edison Swan
Texas Instruments
Westinghouse Brake

REFRIGERATION CONTROLLERS
★ *Circle No.* 794
Bristol Inst.
British Arca Regulators
Brit. Klockner Switchgear
Cambridge Instrument
Danfoss
Dewhirst & Partner
Elliott Brothers
Frigidaire
Integra Leeds
Sauter Controls
S.E. Laboratories
Teddington Ind. Equip.
Teddington Refrigeration

RELAYS, electric. See also **Solenoids**

RELAYS, electric—chopper
★ *Circle No.* 795
Clare, C. P.
Elliott Brothers
Elliott Nucleonics
Ericsson Telephones
George Kent
Honeywell Controls
Hasler Telegraph Works
Landis & Gyr
Siemens Edison Swan
Simmonds, L. E.
Stewart Aero Supply
Telephone Manufacturing

RELAYS, electric—contactors
★ *Circle No.* 796
Allen West & Co.
Arrow Electric Switches
Asquith Electrics
Bray, E. N.
Brookhirst Igranic
C.N.S. Instruments
Danfoss
Dewhurst & Partner
Donovan Electrical
Electro Methods
Elliott Brothers
Electrical Apparatus
Engel & Gibbs
Electro-Mechanical Systems
Fuel Efficiency
Hendrey Relays
Hirst Electronics
Jack Davis Relays
John Morris Elec. Eng.
Kingston Control Systems
Klockner Moeller
Lancashire Dynamo Nevelin
Londex
Magnet Devices
Morecambe Electrical
M.T.E. Control Gear
Nalder Bros. & Thompson
Plessey Co.
Rheostatic Co.
Robinson, D.
Sauter Controls
Sciaky Electric Welding
Sharp Control Gear
Simplex Electric
Square D
Stewart Aero Supply
Vlasto Clark & Watson

RELAYS, electric—electronic
★ *Circle No.* 797
Automatic Telephone
B. & R. Relays
British Sarozal
Bruce Peebles
Brush Electrical
Craven Electronics
Dewrance
Elcontrol
Electric Remote Control
Electrical Thermometer
Electronic Switchgear
Elliott Brothers
Ericsson Telephones
Evans Electronic Develop.
Jack Davis Relays
James Gordon
Lancashire Dynamo Elect.
Landis & Gyr
Londex
Magnet Devices
Nalder Bros. & Thompson
Newman Industries
Plessey Co.
Siemens Edison Swan
Sciaky Electric Welding
Stewart Aero Supply
Standard Telephones
Sunvic Controls
Sutton Coldfield Elec. Eng.
Tyer
Vernons Industries

RELAYS, electric—differential
★ *Circle No.* 798
B. & R. Relays
Electric Remote Control
English Electric
Engel & Gibbs
Bray, E. N.
Evershed & Vignoles
Elliott Brothers
Fuller Electric
Ferranti
John Thompson Instrument
Jack Davis Relays
Londex
Magnet Devices
Muirhead
Plessey Co.
Simmonds, L. E.
Sunvic Controls

RELAYS, electric—high voltage
★ *Circle No.* 799
Autophone
B. & R. Relays
Bray, E. N.
British Sarozal
Electric Remote Control
Electrical Apparatus
Elliott Brothers
Engel & Gibbs
English Electric
Fuller Electric
Hendrey Relays
Jack Davis Relays
Londex
Magnet Devices
Magnetic Controls
Mervyn Instruments
Plessey Co.
Sanders (Electronics), W. H.
Simmonds, L. E.
Standard Telephones

RELAYS, electric—latch
★ *Circle No.* 800
Arrow Electric Switches
Austinlite
B. & R. Relays
Bray, E. N.
Brookhirst Igranic
Clarke, C. P.
C.W.C. Equipment
Dewhurst & Partner
Electric Remote Control
Electrical Apparatus
Electro Magnetic Control
Electro-Mechanical Systems
Elliott Brothers
Engel & Gibbs
Jack Davis Relays
Landis & Gyr
Londex
Magnet Devices
Magnetic Controls
Morecambe Electrical
M.T.E. Control Gear
Page Engineering
Robinson, D.
Sanders (Electronics), W. H.
Sciaky Electric Welding
Simmonds, L. E.
Square D
Telephone Manufacturing
Thorn Electrical Ind.

RELAYS, electric—magnetic
★ *Circle No.* 801
A.D.S. Relays Limited
Arrow Electric Switches
Automatic Telephone
Autophone
B. & R. Relays
Brookhirst Igranic
Cathodeon
Clare, C. P.
Dewhurst & Partner
Diamond H Switches
Donovan Electrical
Electrical Apparatus
Electric Remote Control
Electro Magnetic Control
Electro Methods
Electrical Thermometer
Elliott Brothers
Engel & Gibbs
English Electric
Ericsson Telephones
Ferranti
Fuel Efficiency
Hendrey Relays
Jack Davis Relays
John Morris Elec. Eng.
Landis & Gyr
Londex
Magnet Devices
Magnetic Controls
Morecambe Electrical
M.T.E. Control Gear
N.S.F.
Page Engineering
Plessey Co.
Robinson, D.
Sanders (Electronics), W. H.
Sharp Control Gear
Simmonds, L. E.
Square D
Stewart Aero Supply
Standard Telephones
Telephone Manufacturing
Wilkinson (Croydon), L.
Woden Transformer

RELAYS, electric—mercury
★ *Circle No.* 802
B. & R. Relays
Clare, C. P.
C.N.S. Instruments
Electric Remote Control
Electrical Thermometer
Electro Magnetic Control
Electro Methods
Elliott Brothers
Engel & Gibbs
Hendrey Relays
I.A.C.
Isenthal
Londex
Magnetic Controls
Robinson, D.
Simmonds, L. E.

RELAYS, electric—miniature
★ *Circle No.* 803
Automatic Telephone
B. & R. Relays
British Sarozal
Clare, C. P.
Diamond H Switches
Electric Remote Control
Electrical Thermometer
Electro Magnetic Control
Electro Methods
Elliott Brothers
Engel & Gibbs
Ericsson Telephones
Jack Davis Relays
Louis Newmark
Leland Instruments
Londex
Magnet Devices
N.S.F.
Oliver Pell
Page Engineering
P.A.R.
Plessey Co.
Robinson, D.
Siemens Edison Swan
Simmonds, L. E.
Stewart Aero Supply
Standard Telephones
Thorn Electrical Ind.
Wilkinson (Croydon), L.
Woden Transformer

RELAYS, electric—moving coil
★ *Circle No.* 804
Austinlite
Clare, C. P.
Electrical Apparatus
Electro Methods
Elliott Brothers
Everett Edgcumbe
Evershed & Vignoles
G.E.C.
Jack Davis Relays
Landis & Gyr
Page Engineering
Record Elec.
Robinson, D.
Salford Elec. Instruments
Sangamo Weston
Smiths Industrial Inst.
Stewart Aero Supply
Thorn Electrical Ind.
Westool

RELAYS, electric—polarized
★ *Circle No.* 805
Automatic Telephone
B. & R. Relays
Clare, C. P.
Cole (Overseas), R. H.
Elliott Brothers
English Electric
Ericsson Telephones
Fuller Electric
G.E.C.
Hasler Telegraph Works
Jack Davis Relays
Landis & Gyr
Simmonds, L. E.
Standard Telephones
Telephone Manufacturing
Wilkinson (Croydon), L.

RELAYS, electric—power
★ *Circle No.* 806
B. & R. Relays
Bray, E. N.
Diamond H Switches
Donovan Electrical
Electric Remote Control
Electro Magnetic Control
Engel & Gibbs
English Electric
Fuller Electric
G.E.C.
Hendrey Relays
Jack Davis Relays
Landis & Gyr
Londex
Magnet Devices
Magnetic Controls
Nalder Bros. & Thompson
Plessey Co.
Robinson, D.
Simmonds, L. E.
Standard Telephones
Thorn Electrical Ind.

RELAYS, electric—sensitive
★ *Circle No.* 807
B. & R. Relays
Bray, E. N.
Coventry Controls
Electric Remote Control
Electrical Thermometer

★ *For further details circle on card facing page 214*

Electro Magnetic Control
Elliott Brothers
English Electric
Engel & Gibbs
Ericsson Telephones
G.E.C.
Harvey Electronics
Hendrey Relays
Jack Davis Relays
Leland Instruments
Londex
Magnet Devices
Plessey Co.
Robinson, D.
Simmonds, L. E.
Standard Telephones
Telephone Manufacturing
Wilkinson (Croydon), L.
Woden Transformer

RELAYS, electric—telephone
★ *Circle No.* 808
A.D.S. Relays Limited
Automatic Telephone
Autophone
B. & R. Relays
British Sarozal
Electric Remote Control
Elliott Brothers
Engel & Gibbs
Ericsson Telephones
Hasler Telegraph Works
Jack Davis Relays
Landis & Gyr
Londex
Magnet Devices
Magnetic Controls
Oliver Pell
Plessey Co.
Robinson, D.
Sanders (Electronics), W. H.
Siemens Edison Swan
Simmonds, L. E.
Standard Telephones
Telephone Manufacturing
Wilkinson (Croydon), L.

RELAYS, electric—time delay
★ *Circle No.* 809
Allied Electronics
Austinlite
Automatic Telephone
B. & R. Relays
Bray, E. N.
Brookhirst Igranic
Brush Electrical
Coventry Controls
Dewhurst & Partner
Donovan Electrical
Electric Remote Control
Electrical Apparatus
Electrical Thermometer
Electro Magnetic Control
Electro Methods
Elliott Brothers
Engel & Gibbs
Ericsson Telephones
Fuller Electric
G.E.C.
Hasler Telegraph Works
Hendrey Relays
Jack Davis Relays
John Morris Elec. Eng.
Kingston Control Systems
Landis & Gyr
Londex
Magnet Devices
Magnetic Controls
M.T.E. Control Gear
Morecambe Electrical
Nalder Bros. & Thompson
Plessey Co.
Page Engineering
Robinson, D.
Siemens Edison Swan
Simmonds, L. E.
Smith Hobson
Square D
Sunvic Controls
Vernons Industries
Vernon Instrument
Welmec Corporation

RELAYS, hydraulic
★ *Circle No.* 810
British Arca Regulators
Dowty Equipment
Electroflo Meters
Electro-Hydraulics
Hivac
Hobson, H. M.
Integral
Muirhead
Reavell-Fahie

RELAYS, pneumatic—adding
★ *Circle No.* 811
Bailey Meters and Control
British Arca Regulators
Cheltenham Autocontrols
Electroflo Meters
Electro-Hydraulics
George Kent
James Gordon
Sauter Controls
Sunvic Controls
Taylor Controls

RELAYS, pneumatic—multiplying
★ *Circle No.* 812
Bailey Meters & Control
British Arca Regulators
Cheltenham Autocontrols
Electroflo Meters
Electro-Hydraulics
George Kent
James Gordon
Sauter Controls
Sunvic Controls

RELAYS, pneumatic—proportioning
★ *Circle No.* 813
Bailey Meters & Control
British Arca Regulators
Cheltenham Autocontrols
Drayton Regulators
Electroflo Meters
Evershed & Vignoles
Electro-Hydraulics
Fisher Governor
George Kent
James Gordon
Sauter Controls
Sunvic Controls

REMOTE INDICATION AND CONTROL, electrical—current signalling
★ *Circle No.* 814
Austinlite
Automatic Telephone
Automation Systems
Bailey Meters & Control
Bristol Inst.
Bruce Peebles
C.J.R.
Craven Electronics
Dewhurst & Partner
Dewrance
Dowty Nucleonics
Electric Remote Control
Electroflo Meters
Elliott Brothers
Ericsson Telephones
Everett Edgcumbe
Evershed & Vignoles
Fuel Efficiency
G.E.C.
George Kent
Graseby Instruments
Gresham Developments
Hendrey Relays
Honeywell Controls
Integra Leeds
K.D.G. Instruments
Lancashire Dynamo Elect.
Landis & Gyr
Laurence Scott
Lock, A. M.
Magneta Time Co.
Magnetic Controls
Page Engineering
Parkinson Cowan Instruments
Reavell-Fahie
Sargrove Electronics
Sound Diffusion
Standard Telephones
Teddington Ind. Equip.
Vernon Instrument
Walker Crosweller
W.S. Electronics

REMOTE INDICATION AND CONTROL, electrical—frequency signalling
★ *Circle No.* 815
Austinlite
Automatic Telephone
Armstrong Whitworth Equip.
Bristol Inst.
Bruce Peebles
Craven Electronics
Elliott Brothers
Everett Edgcumbe
G.E.C.
Gresham Developments
Honeywell Controls
Integra Leeds
Lancashire Dynamo Elect.
Laurence Scott
Magneta Time Co.
Marconi W. T.
Parkinson Cowan Instruments
Rank Cintel
Sargrove Electronics
Sound Diffusion
Standard Telephones
Teddington Ind. Equip.
Walker Crosweller
W.S. Electronics

REMOTE INDICATION AND CONTROL, electrical — impulse signalling
★ *Circle No.* 816
Armstrong Whitworth Equip.
B. & R. Relays
Bristol Inst.
Bruce Peebles
Electric Remote Control
Elliott Brothers
Elliot Nucleonics
Ericsson Telephones
G.E.C.
George Kent
Gilmoor Control Systems
Graseby Instruments
Gresham Developments
Hasler Telegraph Works
IBM United Kingdom
Lancashire Dynamo Elect.
Landis & Gyr
Magneta Time Co.
Magnetic Controls
Marconi W.T.
Measurement Limited
Parkinson Cowan Instruments
Plessey Co.
Rank Cintel
Siemens Edison Swan
Sound Diffusion
Sutton Coldfield Elec. Eng.
Teddington Ind. Equip.
Vernon Instrument

REMOTE INDICATION AND CONTROL, electrical—position or ratio signalling (such as resistance slidewire bridges, inductance bridges, or a.c. self-synchronous motors—Selsyns, synchros, etc.)
★ *Circle No.* 817
Appleby & Ireland
Aveley Electric
Bailey Meters & Control
Bruce Peebles
Craven Electronics
Electroflo Meters
Elliott Brothers
Evershed & Vignoles
Fielden Electronics
Firth Cleveland Instruments
George Kent
Graseby Instruments
Gresham Developments
Honeywell Controls
Harvey Electronics
Integra Leeds
Kelvin & Hughes
Ketay
K.D.G. Instruments
Lancashire Dynamo Elect.
Mawdsley's
Muirhead
Parkinson Cowan Instruments
Parmeko
Pullin, R. B.
Reavell-Fahie
Research & Control Inst.
Servo & Electronic Sales
Servo Units
Smiths Industrial Inst.
Sperry Gyroscope
Telemeters
Vernon Instrument

REMOTE INDICATION AND CONTROL, electrical—voltage signalling
★ *Circle No.* 818
Austinlite
Bailey Meters & Control
Bruce Peebles
Brush Electrical
Elliott Brothers
Elliott Nucleonics
Ericsson Telephones
Evershed & Vignoles
Fuel Efficiency
Gresham Developments
Honeywell Controls
K.D.G. Instruments
Lancashire Dynamo Elect.
Magnetic Controls
Page Engineering
Reavell-Fahie
Research & Control Inst.
Servo Units
Sigma Inst.
Sound Diffusion
Sperry Gyroscope
Teddington Ind. Equip.

REMOTE INDICATION AND CONTROL, mechanical
★ *Circle No.* 819
Addison Electric
Armstrong Whitworth Equip.
Bailey Meters & Control
B. & K. Labs.
B. & R. Relays
Bristol Inst.
British Central Elec.
British Sarozal
Bruce Peebles
Cambridge Instrument
Dewrance
Electroflo Meters
Electrotechnic Ltd.
Elliott Brothers
General Controls
Graseby Instruments
H. & B. Precision Eng.
Hasler Telegraph Works
Hobson, H. M.
Icknield Engineering
Instrument Installations
Magneta Time Co.
Negretti & Zambra
Paton Hawksley
Pelapone Engines
Reavell-Fahie
Samson Controls
S.E. Laboratories
Sound Diffusion
Southern Instruments
Taylor Controls
Teddington Ind. Equip.
Teleflex Products
Trumeter
Veeder-Root
Vernon Instrument
Westinghouse Brake
West Instrument
White Dental Mfg.

RESISTANCE THERMOMETER BULBS
★ *Circle No.* 820
Bailey Meters & Control
Bristol Inst.
Bush, Beach & Segner Bayley
Cambridge Instrument
C.N.S. Instruments
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Fielden Electronics
Foster Instrument
Foxboro-Yoxall
Headland Eng. Developments
James Gordon
Kandem Electrical
Kelvin & Hughes
Sangamo Weston
Smith & Sons (England), S.
Sunvic Controls
Swartwout
Tinsley, H.
West Instrument

RESISTORS, fixed—carbon
★ *Circle No.* 821
Anders Electronics
Aveley Electric
British Central Elec.
Bush, Beach & Segner Bayley
Erie Resistor
Farnell Instruments
Holiday & Hemmerdinger
Kendall & Mousley
Le Carbone (Great Britain)
Morgan Crucible Co.
Morganite Resistors
Radiospares
Stanley Palmer, G. A.
Stewart Aero Supply
Welwyn Elec. Labs.
Wilkinson (Croydon), L.

RESISTORS, fixed—high stability
★ *Circle No.* 822
Anders Electronics
Aveley Electric
Birch, H. A.
British Central Elec.
Bush, Beach & Segner Bayley
Electrothermal Eng.
Erie Resistor
Farnell Instruments
Holiday & Hemmerdinger
Kendall & Mousley
Lawrence Electronics
Le Carbone (Great Britain)
Miles-Hivolt
Painton & Co.
Plessey Co.
Radiospares
Standard Telephones
Stanley Palmer, G. A.
Stewart Aero Supply
Welwyn Elec. Labs.
Wilkinson (Croydon), L.

RESISTORS, fixed—precision wire-wound
★ *Circle No.* 823
A.E.W.
Alma Components
Anders Electronics
Aveley Electric
British Central Elec.
British Sarozal
Cambridge Instrument
Doran Instrument
Electronic Components
Electro-Mechanical Systems
Electrothermal Eng.
Ernest Turner
Farnell Instruments
Fox, P. X.
General Controls
Kandem Electrical
Kendall & Mousley
Labgear
Lawrence Electronics
McMurdo Instrument Co.
Miles-Hivolt
Muirhead
Painton & Co.
Plessey Co.
Pye, W. G.
Radiospares
Rivlin Instruments
Stanley Palmer, G. A.
Stewart Aero Supply
Welwyn Elec. Labs.
White Electrical Inst.
Wilkinson (Croydon), L.

RESISTORS, fixed—sub-miniature
★ *Circle No.* 824
A.E.W.
Alma Components
Ardente Acoustic Lab.
Aveley Electric
British Central Elec.
Cole (Overseas), R. H.
Erie Resistor
Farnell Instruments
General Controls
Painton & Co.
Plessey Co.
Standard Telephones
Stanley Palmer, G. A.
Stewart Aero Supply
Welwyn Elec. Labs.

RESISTORS, fixed—temperature sensitive
★ *Circle No.* 825
Aveley Electric
British Central Elec.
Electrothermal Eng.
Le Carbone (Great Britain)
Plessey Co.
Standard Telephones
Texas Instruments

RESISTORS, fixed — wire-wound
★ *Circle No.* 826
A.E.W.
Alma Components
Aveley Electric
Birch, H. A.
British Central Elec.
British Elc. Resistance Co.
British Sarozal
Brookhirst Igranic
Bulgin, A. F.
Cressall Mfg.
Doran Instrument
Electronic Components
Electrothermal Eng.
Erie Resistor
Ernest Turner
Farnell Instruments
Fawcett Preston
General Controls
G.E.C.
Holiday & Hemmerdinger
Isenthal
John Morris Elec. Eng.
Kendall & Mousley
Labgear
Miles-Hivolt
Muirhead
Oliver Pell
Painton & Co.
Plessey Co.
Radiospares
Resistances
Stanley Palmer, G. A.
Stewart Aero Supply
Tinsley, H.
Welwyn Elec. Labs.
White Electrical Instruments
Wilkinson (Croydon), L.

RESISTORS, flexible
★ *Circle No.* 827
Electrothermal Eng.
Fawcett Preston
Plessey Co.
Welwyn Elec. Labs.

RESISTORS, variable—composition
★ *Circle No.* 828
Anders Electronics
Aveley Electric
Dunlop Rubber
Holiday & Hemmerdinger
Morganite Resistors
N.S.F.
Plessey Co.
Radiospares
Reliance Mfg. Co.
Stewart Aero Supply
Wilkinson (Croydon), L.

RESISTORS, variable — subminiature
★ *Circle No.* 829
Amphenol (G.B.)
Anders Electronics
Aveley Electric
Ferranti
Fox, P. X.
Miles-Hivolt
Plessey Co.
Radiospares
Reliance Mfg. Co.
Stewart Aero Supply
Thorn Electrical Ind.

RESISTORS, variable — wire-wound
★ *Circle No.* 830
Amphenol (G.B.)
Anders Electronics
Aveley Electric
Birch, H. A.
British Sarozal
Brookhirst Igranic
Bulgin, A. F.
Colvern
Cressall Mfg.
Doran Instrument
Electronic Components
Farnell Instruments
Ferranti
Fox, P. X.
G.E.C.
General Controls
Holiday & Hemmerdinger
Isenthal
John Morris Elec. Eng.
Kendall & Mousley
Miles-Hivolt
Painton & Co.
Plessey Co.
Radiospares
Reliance Mfg. Co.
Resistances
Stewart Aero Supply
Welwyn Elec. Labs.
Wilkinson (Croydon), L.
Zenith Electric

ROTARY TRANSFORMERS. See **Converters**

SALINITY INDICATORS
★ *Circle No.* 831
Cossor Instruments
Electronic Switchgear
Evershed & Vignoles
Griffin & George

SATURABLE REACTORS. See **Amplifiers, magnetic**

SCANNING EQUIPMENT. See also **Data logging equipment**
★ *Circle No.* 832
A.E.I.
Airtech
Bruce Peebles
Cambridge Instrument
C.N.S. Instruments
Decca Radar
De Havilland Propellers
Digital Engineering
Electroflo Meters
Electro-Mechanical Systems
Elliott Brothers
Elliott Nucleonics
Epsylon Industries
Ericsson Telephones
Fielden Electronics
G.E.C.
Gilmoor Control Systems
Glass Developments

★ *For further details circle on card facing page 214*

Honeywell Controls
Integra Leeds
James Scott Elec. Eng.
Lindars Automation
Lintronic
Marconi Instruments
Panellit
Peto Scott
Rank Cintel
Solartron
Sunvic Controls

SCINTILLATION COUNTERS. See Counters, scintillation

SEAL RINGS (O, U and V) ★ Circle No. 833
Dowty Seals
Dunlop Rubber
George Angus
Hall & Hall
Henry Brakhane
James Walker
Joseph Lucas
Joseph Lucas (H. & C.)
N.G.N. Electrical
Polypenco
Precision Rubbers
Super Oil Seals

SEALS—graphite ★ Circle No. 834
Le Carbone (Great Britain)

SEALS—mechanical ★ Circle No. 835
Danfoss
Dowty Seals
George Angus
James Walker
Knitmesh
Le Carbone (Great Britain)
Ronald Trist
Super Oil Seals

SELSYNS. See Remote indication and control, electrical

SEMICONDUCTOR MATERIALS ★ Circle No. 836
Brush Crystal
Johnson Matthey
Mining & Chemical Prod.
Newmarket Transistors
Plessey Co.
R.C.A. (G.B.)
Texas Instruments

SEQUENCE CONTROLLERS ★ Circle No. 837
Atkins Robertson
Automa Engineering
Bray, E. N.
Bristol Inst.
Brit. Klockner Switchgear
British Sarozal
Bruce Peebles
British Federal Welder
Cambridge Instrument
C.J.R.
Craven Electronics
De Havilland Propellers
Delta Technical Services
Dewhurst & Partner
Digital Engineering
Elcontrol
Electric Remote Control
Electroflo Meters
Electronic Switchgear
Elliott Brothers
Elliott Nucleonics
Ericsson Telephones
G.E.C.
Gresham Developments
Jones Tate
Lancashire Dynamo Elect.
Magnetic Controls
Mullard Equipment
Nickols Automatics
Newman Industries
Research & Control Inst.
Sargrove Electronics
Sharp Control Gear
Southern Instruments
Sterling Instruments
Taylor Controls
Telemeters
Timothy Eaton

SERVOSYSTEM ANALYSERS. See Frequency response analysers

SERVOSYSTEM COMPONENT KITS ★ Circle No. 838
Bruce Peebles
Feedback
Harvey Electronics
Integra Leeds
Pioneer Designs
Sealey Engineering
Servo & Electronics Sales
Servomex Controls
Servo Units
Short Bros. & Harland
Vactric Control Equipment
White & Riches

SHIP STABILIZING SYSTEMS See Automatic ship stabilizing systems

SIGNAL GENERATORS. See Generators and Oscillators

SIMULATORS. See also Computers, analogue

SIMULATORS—aircraft ★ Circle No. 839
Air Trainers Link
Electronic Associates
Elliott Brothers
English Electric
Evershed & Vignoles
Louis Newmark
Marconi, W. T.
Miles-Hivolt
Panellit
Saunders Roe
Short Bros. & Harland
White & Riches

SIMULATORS—feel ★ Circle No. 840
Air Trainers Link
Electronic Associates
Hobson, H. M.
Miles-Hivolt
Panellit
Saunders-Roe

SIMULATORS—general research ★ Circle No. 841
Air Trainers Link
Bruce Brothers
Electronic Associates
Elliott Brothers
Louis Newmark
Miles-Hivolt
Newman Industries
Panellit
Rank Cintel
Royston Instruments
Short Bros. & Harland
Saunders-Roe
White & Riches

SIMULATORS—nuclear reactor ★ Circle No. 842
A.E.I.
Air Trainers Link
Electronic Associates
Elliott Brothers
Elliott Nucleonics
English Electric
Integra Leeds
Miles-Hivolt
Panellit
Saunders-Roe
Short Bros. & Harland
Solartron

SIMULATORS—personnel training ★ Circle No. 843
Air Trainers Link
Bruce Peebles
Electronic Associates
Elliott Brothers
Elliott Nucleonics
Miles-Hivolt
M. L. Aviation Co.
Panellit
Saunders-Roe
Solartron
Telecommunications Inst.
White & Riches

SIMULATORS—radar, tactical ★ Circle No. 844
Air Trainers Link
A.P.T. Electronic Indust.
Electronic Associates
Marconi, W. T.
Miles-Hivolt
Panellit
Rank-Cintel
Solartron
Telecommunication Inst.

SLIP RINGS—flat ★ Circle No. 845
I.D.M. Electronics

SLIP RINGS—miniature, instrument ★ Circle No. 846
Kelvin & Hughes
I.D.M. Electronics

SLIP RINGS—ring ★ Circle No. 847
Graseby Instruments
I.D.M. Electronics

SMOKE-DENSITY INDICATORS ★ Circle No. 848
Baldwin Industrial Controls
British Central Elec.
Bailey Meters & Control
Craven Electronics
Electroflo Meters
Fielden Electronics
Foster Instrument
G.E.C.
Glass Developments
Griffin & George
Integra Leeds
John Thompson Instrument
Kelvin & Hughes
Lancashire Dynamo Elect.
Lock, A. M.
Londex
Newman Industries
Photoelectronics (M.O.M.)
Radiovisor Parent
Ronald Trist
Sargrove Electronics

SOLENOIDS. See Actuators, electric solenoid

STORAGE UNITS, computer—delay lines ★ Circle No. 849
Automation Consultants
Cossor Instruments
Gresham Developments
Louis Newmark
Mullard Equipment
Siemens Edison Swan

STORAGE UNITS, computer—ferrite cores ★ Circle No. 850
Automation Consultants
Gresham Developments
Lintronic
Mullard
Newport Instruments
Plessey Co.
R.C.A. (G.B.)
Standard Telephones

STORAGE UNITS, computer—magnetic drum ★ Circle No. 851
Automatic Telephone
Epsylon Industries
Rank Cintel
R.C.A. (G.B.)
Sperry Gyroscope
Standard Telephones

STORAGE UNITS, computer—magnetic tape ★ Circle No. 852
Ampex Electronics
Decca Radar
Electro-Mechanical Systems
Electronic Associates
Epsylon Industries
Gresham Developments
New Electronic Products
R.C.A. (G.B.)
Royston Instruments
Thermionic Products

STORAGE UNITS, computer—tubes ★ Circle No. 853
Cathodeon
Lintronic
Mullard Equipment
R.C.A. (G.B.)

SOUND LEVEL INDICATORS ★ Circle No. 854
Aveley Electronic
Allied Electronics
Claude Lyons
Dawe Instruments
Ernest Turner
Farnell Instruments
Standard Telephones
Taylor Electrical

SPECIFIC GRAVITY INDICATORS. See Density and specific gravity indicators

SPECTROMETERS and spectrophotometers, direct reading—infra-red ★ Circle No. 855
Bellingham & Stanley
Gallenkamp, A.
Hilger & Watts
Joyce Loebel
Mervyn Instruments
Perkin-Elmer
Unicam Instruments

SPECTROMETERS and spectrophotometers, direct reading—mass ★ Circle No. 856
20th. Century Electronics

SPECTROMETERS and spectrophotometers, direct reading—microwave ★ Circle No. 857
B. & K. Labs.
Research & Control Inst.

SPECTROMETERS and spectrophotometers, direct reading-nuclear magnetic resonance ★ Circle No. 858
Fairey
Mullard Equipment

SPECTROMETERS and spectrophotometers, direct reading—paramagnetic ★ Circle No. 859
Research & Control Inst.

SPECTROMETERS and spectrophotometers, direct reading—visual and ultra-violet ★ Circle No. 860
Bellingham & Stanley
Evans Electroselenium
Gallenkamp, A.
Griffin & George
Hilger & Watts
Joyce Loebl
Optical Works
Perkin-Elmer
Southern Instruments
Unicam Instruments

SPECTROMETERS and spectrophotometers, direct reading—X-ray fluorescence ★ Circle No. 861
Hilger & Watts
Solartron

SPEED MEASURING INSTRUMENTS. See Tachometers

STANDARD CELLS. See Cells, electric

STATIC SWITCHING EQUIPMENT. See Switches, static

STRAIN GAUGES—bonded ★ Circle No. 862
Bryans Aeroequipment
Farnell Instruments
Langham Thompson, J.
Lintronic
Research & Control Inst.
Saunders-Roe
Technograph
Teddington Ind. Equip.
Tinsley, H.

STRAIN GAUGES—unbonded ★ Circle No. 863
Bryans Aeroequipment
Ericsson Telephones
G.E.C.
Langham Thompson, J.
Lintronic
Paton Hawksley
Research & Control Inst.
Technical Ceramics
Technograph
Teddington Ind. Equip.
Tinsley, H.

STRIP-CHART RECORDERS See Recorders

STROBOSCOPES ★ Circle No. 864
Allied Electronics
Claude Lyons
Dawe Instruments
Farnell Instruments
Graseby Instruments
Giesler, C. F. R.
Lancashire Dynamo Elect.
Research & Control Inst.
Savage & Parsons
Timothy Eaton
Welmec Corporation

SUPERVISORY SYSTEMS See Remote indication and control

SWITCHES—control ★ Circle No. 865
Allen West & Co.
Arrow Electric Switches
Asquith Electrics
Austinlite
Birfield Industries
Black Automatic Controls
Bray, E. N.
British Central Elec.
Brookhirst Igranic
B.S.A. (Tools Division)
Crater Products
Delta Technical Services
Dewhurst & Partner
Diamond H Switches
Dowty Nucleonics
Electric Remote Control
Electronic Components
English Electric
G.E.C.
Graseby Instruments
Hendrey Relays
K.D.G. Instruments
Majestic Electric
Plessey Co.
Pye (Switch Div.), W. G.
Sharp Control Gear
Siemens Edison Swan
Simplex Electric
Standard Telephones
Stewart Aero Supply
Square D
Sunvic Controls
Teddington Ind. Equip.
Watford Electric

SWITCHES—electronic ★ Circle No. 866
A.E.I.
Allied Electronics
Ariel Sound
Arrow Electric Switches
Automation Consultants
Black Automatic Controls
B. & R. Relays
British Federal Welder
B.S.A. (Tools Division)
Brush Electrical
Craven Electronics
Elcontrol
Electronic Components
Electronic Switchgear
Ericsson Telephones
Farnell Instruments
H. & B. Precision Eng.
Lancashire Dynamo Elect.
Lock, A. M.
Newman Industries
Plessey Co.
Pye (Switch Div.), W. G.
Siemens Edisonswan
S.S. Electronics
Stewart Aero Supply
Standard Telephones
Sunvic Controls
Sutton Coldfield Elec. Eng.
Technograph
Venner Electronics
Vidor Batteries
Woden Transformer

SWITCHES—key ★ Circle No. 867
Autophone
British Central Elec.
Brookhirst Igranic
B.S.A. (Tools Division)
Bulgin, A. F.
Crater Products
Dewhurst & Partner
Ericsson Telephones
Graseby Instruments
Hasler Telegraph Works
Jack Davis Relays
Law & Plumtree
Muirhead
Plessey Co.
Standard Telephones
Stanley Palmer, G. A.
Stewart Aero Supply
Square D
Telephone Manufacturing
Wilkinson (Croydon), L. A.

SWITCHES—lever or toggle ★ Circle No. 868
Arcolectric Switches
Ardente Acoustic Lab.
Arrow Electric Switches
Armstrong Whitworth Equip.
British Central Elec.
Brookhirst Igranic
B.S.A. (Tools Division)
Bulgin, A. F.
C.W.C. Equipment
Dewhurst & Partner
Diamond H Switches
Dowty Nucleonics
Ericsson Telephones
Flight Refuelling
G.E.C.
Graseby Instruments
Hasler Telegraph Works
Holiday & Hemmerdinger
Law & Plumtree
N.S.F.
Page Engineering
Painton & Co.
Plessey Co.
Pye (Switch Div.), W. G.
Radiospares
Simplex Electric
Standard Telephones
Stewart Aero Supply
Telephone Manufacturing
Thermal Control Company
Wilkinson (Croydon), L.

SWITCHES—capacitance ★ Circle No. 869
B.S.A. (Tools Division)
Crater Products
Ericsson Telephones
Jack Davis Relays
Kendall & Mousley
Muirhead
N.S.F.
Plessey Co.
Radiospares
Stewart Aero Supply
Telephone Manufacturing
Vidor Batteries

SWITCHES—mercury
I.A.C.

SWITCHES—micro ★ Circle No. 870
Arcolectric Switches
Arrow Electric Switches
British Central Elec.
B.S.A. (Tools Division)
Bulgin, A. F.
Burgess Products
Craig and Derricott
Danfoss
Dowty Nucleonics
Holiday & Hemmerdinger
Pye (Switch Div.), W. G.
Stewart Aero Supply
Square D

SWITCHES—push-button ★ Circle No. 871
Allen West & Co.
Arcolectric Switches
Arrow Electric Switches
Asquith Electrics
Autophone
British Central Elec.
Brit. Klockner Switchgear
Brookhirst Igranic
B.S.A. (Tools Division)
Bulgin, A. F.
Burgess Products
Craig & Derricott
Crater Products
Dewhurst & Partner
Donovan Electrical
Dowty Nucleonics
Elliott Brothers
Elliott Nucleonics
Ericsson Telephones
Farnell Instruments
Graseby Instruments
Hasler Telegraph Works
Jack Davis Relays
Londex
Magnet Devices
M.B. Metals
Morecambe Electrical
M.T.E. Control Gear
N.S.F.
Page Engineering
Painton & Co.
Plessey Co.
Radiospares
Simplex Electric
Square D
Stewart Aero Supply
Thorn Electrical Ind.
Watford Electric
Welmec Corporation
Woden Transformer

SWITCHES—rotary, hand-driven ★ Circle No. 872
Arcolectric Switches

★ For further details circle on card facing page 214

Ardente Acoustic Lab.
Arrow Electric Switches
Asquith Electrics
Austinlite
British Central Elec.
Brookhirst Igranic
B.S.A. (Tools Division)
Bulgin, A. F.
Chilton Electric
Craig & Derricott
Crater Products
Croydon Precision Instrument
Dewhurst & Partner
Diamond H Switches
Electric Remote Control
Electronic Components
G.E.C.
Hendrey Relays
Kendall & Mousley
Law & Plumtree
Majestic Electric
Muirhead
N.S.F.
Plessey Co.
Page Engineering
Pye, W. G.
Radiospares
Square D
Stewart Aero Supply
Tinsley, H.

SWITCHES—rotary, motor-driven
★ *Circle No.* 873
Armstrong Whitworth Equip.
Austinlite
British Central Elec.
Brookhirst Igranic
B.S.A. (Tools Division)
Chilton Electric
Croydon Precision Instrument
Electric Remote Control
Electronic Components
Graseby Instruments
I.D.M. Electronics
N.S.F.
Plessey Co.
Pye, W. G.
Robinson, D.
Sharp Control Gear
Stewart Aero Supply
Vactric Control Equipment

SWITCHES—slide
★ *Circle No.* 874
Arcolectric Switches
Ardente Acoustic Lab.
Arrow Electric Switches
British Central Elec.
B.S.A. (Tools Division)
Bulgin, A. F.
Electronic Components
N.S.F.
Plessey Co.
Radiospares

SWITCHES—static
★ *Circle No.* 875
A.E.I.
British Central Elec.
Brookhirst Igranic
Bruce Peebles
B.S.A. (Tools Division)
Dewhurst & Partner
Elliott Nucleonics
Gresham Developments
Lancashire Dynamo Elect.
Plessey Co.
Sanders (Electronics), W. H.
Stewart Aero Supply
Woden Transformer

SWITCHES—stud
★ *Circle No.* 876
British Central Elec.
British Elec. Resistance
B.S.A. (Tools Division)
Croydon Precision Instrument
G.E.C.
Muirhead
Painton & Co.

SWITCHES—sub-miniature
★ *Circle No.* 877
Ardente Acoustic Lab.
British Central Elec.
B.S.A. (Tools Division)
Burgess Products
Crater Products
Graseby Instruments
I.D.M. Electronics
N.S.F.
Page Engineering
Plessey Co.
Stewart Aero Supply

SWITCHES—thermal delay
★ *Circle No.* 878
Allied Electronics
B.S.A. (Tools Division)
Brit. Klockner Switchgear
Coventry Controls
Delta Technical Services
Dewhurst & Partner
Electric Remote Control
Hivac
Radiovisor Parent
Siemens Edison Swan

SWITCHES—time
★ *Circle No.* 879
A.E.I.
Allied Electronics
Bivac Air
British Central Elec.
B.S.A. (Tools Division)
B. & R. Relays
Bray, E. N.
Coventry Controls
Crater Products
Dewhurst & Partner
Donovan Electrical
Elcontrol
Electric Remote Control
Electro Magnetic Control
Engel & Gibbs
G.E.C.
Graseby Instruments
Horstmann Gear
Hendrey Relays
Page Engineering
Robinson, D.
Sangamo Weston
Square D
Sterling Instruments
Sunvic Controls
Sutton Coldfield Elec. Eng.
Woden Transformer
Williams (B'ham), R. A.

SWITCHES—uniselector, ratchet-driven
★ *Circle No.* 880
Autophone
Automatic Telephone
British Central Elec.
B.S.A. (Tools Division)
Electric Remote Control
Ericsson Telephones
Graseby Instruments
Hasler Telegraph Works
Jack Davis Relays
N.S.F.
Standard Telephones
Wilkinson (Croydon), L.

SWITCHES—uniselector, motor-driven
★ *Circle No.* 881
Automatic Telephone
British Central Elec.
B.S.A. (Tools Division)
Electric Remote Control
Siemens Edison Swan

SYNCHROS (including Mag-slips). See Remote control electrical

SYNCHRO TEST EQUIPMENT
★ *Circle No.* 882
Bruce Peebles
E.M.O. Instrumentation
Muirhead
Pioneer Designs
Solartron

TACHOMETERS—centrifugal
★ *Circle No.* 883
Gallenkamp, A.

TACHOMETERS—chronometric
★ *Circle No.* 884
Hasler Telegraph Works
Langham Thompson, J.
Rank Cintel
Smith & Sons (England), S.
Thermionic Products
Venner Electronics

TACHOMETERS —drag-cup motor
★ *Circle No.* 885
Hasler Telegraph Works
Smiths Industrial Inst.
Vactric Control Equipment

TACHOMETERS—eddy current
★ *Circle No.* 886
Icknield Engineering
Smiths Industrial Inst.

TACHOMETERS—electric generator, a.c.
★ *Circle No.* 887
British Physical Labs.
British Central Elec.
C.N.S. Instruments
Crompton Parkinson
Evershed & Vignoles
Elliott Brothers
Hasler Telegraph Works
Kandem Electrical
Ketay
Laurence Scott
Muirhead
Metrix Instruments
Pullin, R. B.
Racal Instruments
Record Elec.
Smith & Sons (England), S.
Smiths Industrial Inst.
Stewart Aero Supply
Salford Elec. Instruments
Sperry Gyroscope
Sangamo Weston
Vactric Control Equipment

TACHOMETERS—electric generator, d.c.
★ *Circle No.* 888
British Central Elec.
Evershed & Vignoles
Electro Methods
Elliott Brothers
Mortley Sprague
G.E.C.
Honeywell Controls
Kelvin & Hughes
Laurence Scott
Muirhead
Pullin, R. B.
Record Elec.
Smiths Industrial Inst.
Stewart Aero Supply
Salford Elec. Instruments
Sperry Gyroscope
Vactric Control Equipment
Walter Jones

TACHOMETERS—electronic
★ *Circle No.* 889
Airmec
Atkins Robertson
Allied Electronics
British Physical Labs.
Brush Electrical
Bryans Aeroequipment
C.N.S. Instruments
Craven Electronics
Ericsson Telephones
Erie Resistor
Farnell Instruments
Giesler, C. F. R.
Grünther Ind. Developments
Hobson, H. M.
Integral
Joseph Lucas
Lancashire Dynamo Elect.
Langham Thompson, J.
Metrix Instruments
Paton Hawksley
Rank Cintel
Venner Electronics

TACHOMETERS—impulse
★ *Circle No.* 890
British Physical Labs.
Ericsson Telephones
Firth Cleveland Instruments
Labgear
Record Elec.

TACHOMETERS —revolution counters
★ *Circle No.* 891
Allied Electronics
British Physical Labs.
Carter, B. & F.
Firth Cleveland Instruments
Hasler Telegraph Works
Icknield Engineering
Integral
James W. Carr
Labgear
Langham Thompson, J.
Paton Hawksley
Smith & Sons (England), S.
Smiths Industrial Inst.
Stewart Aero Supply
Thomas Mercer

TEACHING MACHINES. See also Simulators, personnel training
★ *Circle No.* 892
Air Trainers Link
Miles-Hivolt
Panellit
Solartron

TELEMETERING SYSTEMS. See Remote indication and control

TELEPRINTERS
★ *Circle No.* 893
Creed & Co.

TELEVISION EQUIPMENT, industrial
★ *Circle No.* 894
Ampex Electronics
Cathodeon
Electro-Mechanical Systems
Epsylon Industries
Films & Equipments
Farnell Instruments
Lancashire Dynamo Elect.
Magneta Time Co.
Marconi, W. T.
Plessey Co.
Peto Scott
Pye, W. G.
Rank Cintel
Research & Control Inst.
Tyer
Taylor Electrical

TEMPERATURE CONTROLLERS. See also Controllers

TEMPERATURE CONTROLLERS —electric output
★ *Circle No.* 895
Airmec
A.M. Lock
Armstrong Whitworth Equip.
Automation Systems
Bailey Meters & Control
Black Automatic Controls
Bristol Inst.
Brit. Klockner Switchgear
British Sarazol
Bruce Peebles
Cambridge Instrument
C.N.S. Instruments
Coley Thermometers
Craven Electronics
Danfoss
Delta Technical Services
Dewrance
Drayton Regulator
Elcontrol
Electro-Magnetic Control
Electroflo Meters
Elliott Nucleonics
Elliott Brothers
Ether
Evershed & Vignoles
Foster Instrument
Foxboro-Yoxall
Fuel Efficiency
Fielden Electronics
George Kent
Graseby Instruments
Hatfield Instruments
Headland Eng. Developments
Hirst Electronics
Honeywell Controls
Industrial Pyrometer
Integra Leeds
James Gordon
John Thompson Instrument
Kandem Electrical
Kelvin & Hughes
Kingston Control Systems
Lancashire Dynamo Elect.
M.B. Metals
Metrix Instruments
Negretti & Zambra
Parmeko
Plessey Co.
Radiovisor Parent
Research & Control Inst.
Rheostatic Co.
Sargrove Electronics
Short & Mason
Sifam Electric Instruments
Stonebridge Electrical
Swartwout
Teddington Ind. Equip.
Thermal Control Co.
Tyer
Unity Heating
Watford Electric
West Instrument
Winston Electronics

TEMPERATURE CONTROLLERS —pneumatic output
★ *Circle No.* 896
Automation Systems
Bailey Meters & Control
Bristol Inst.
British Arca Regulators
Cambridge Instrument
Cheltenham Autocontrols
Crosby Valve & Eng.
Delta Technical Services
Drayton Regulator
Elec. Steam & Mining
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Fielden Electronics
Foxboro-Yoxall
George Kent
Honeywell Controls
Integra Leeds
James Gordon
Kandem Electrical
Negretti & Zambra
Perl Controls
Reavell-Fahie
Samson Controls
Sunvic Controls
Taylor Controls
Teddington Ind. Equip.

TEMPERATURE INDICATORS. See Thermistors, Thermocouples, Pyrometers, Resistance thermometer bulbs and Thermometers

TEMPERATURE ALARM SYSTEMS
★ *Circle No.* 897
A.E.I.
Automation Systems
Bailey Meters & Control
Bamford, F.
Black Automatic Controls
Bristol Inst.
British Sarazol
Bruce Peebles
Cambridge Instrument
Cheltenham Autocontrols
Delta Technical Services
Drayton Regulator
Electroflo Meters
Electrical Thermometer
Electrotechnic
Elliott Brothers
Elliott Nucleonics
Ether
Evershed & Vignoles
Foster Instrument
Fuel Efficiency
Fielden Electronics
G.E.C.
George Kent
Headland Eng. Dev.
Honeywell Controls
Industrial Pyrometer
Integra Leeds
John Thompson Instrument
Kelvin & Hughes
Kingston Control Systems
Lancashire Dynamo Elect.
Lintronic
Negretti & Zambra
Page Engineering
Panellit
Pelapone Engines
Radiovisor Parent
Short & Mason
Sunvic Controls
Swartwout
Taylor Controls
Teddington Ind. Equip.
Teddington Refrigeration
White & Riches
Zeal, G. H.

TEMPERATURE SENSITIVE PAINTS AND MATERIALS
★ *Circle No.* 898
Bush, Beach, & Segner Bayley
Ether
Griffin & George
Headland Eng. Dev.

TENSION INDICATORS
★ *Circle No.* 899
Cambridge Instrument
Davy & United Instruments
Fred Ferraris
Int. Engineering Concess.
Jack Davis Relays
James W. Carr
Kelvin & Hughes
M.L. Aviation
Research & Control Inst.
Saunders-Roe
Thomas Mercer

TEXTILE TESTING EQUIPMENT
★ *Circle No.* 900
British Sarozal
Bruce Peebles
Bryan Donkin
Ericsson Telephones
Evans Electroselenium
Farnell Instruments
Fielden Electronics
Kelvin & Hughes
Lancashire Dynamo Elect.
Reynolds & Branson
Trumeter

THERMOPILES. See Thermocouples—multi-function

THERMISTORS
★ *Circle No.* 901
Aveley Electric
Cole (Overseas) R. H.
Holiday & Hemmerdinger
Le Carbone (Great Britain)
Mullard
Plessey Co.
Radiospares
Standard Telephones
Texas Instruments
Wayne Kerr Labs.

THERMOCOUPLES—base metal
★ *Circle No.* 902
Anders Electronics
Bailey Meters & Control
B.I.C.C.
Bristol Inst.
British Central Elec.
British Driver Harris
Bush, Beach, & Segner Bayley
Bryan Donkin
Cambridge Instrument
Electroflo Meters
Elliott Brothers
Ether
Foster Instrument
Foxboro-Yoxall
Griffin & George
Honeywell Controls
Industrial Pyrometer
Integra Leeds
James Gordon
Kandem Electrical
Kelvin & Hughes
Land Pyrometers
Pyrotenax
Research & Control Inst.
Sangamo Western
Sifam Electrical Instruments
Technograph
West Instrument
White Electrical Inst.

THERMOCOUPLES—contact type
★ *Circle No.* 903
Bailey Meters & Control
Bristol Inst.
British Central Elec.
Bush, Beach, & Segner Bayley
Cambridge Instrument
Electroflo Meters
Ether
Foster Instrument
Foxboro-Yoxall
Headland Eng. Developments
Honeywell Controls
Industrial Pyrometer
Kelvin & Hughes
Land Pyrometers
Research & Control Inst.
Sifam Electrical Instruments
Wayne Kerr Labs.
West Instrument

THERMOCOUPLES—immersion
★ *Circle No.* 904
Bailey Meters & Control
Bristol Inst.
British Central Elec.
British Sarozal
Bush, Beach, & Segner Bayley
Cambridge Instrument
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Ether
Foster Instrument
Foxboro-Yoxall
Honeywell Controls
Industrial Pyrometer
Integra Leeds
James Gordon
Kandem Electrical
Land Pyrometers
Sifam Electrical Instruments
Wayne Kerr Labs.
West Instrument
White Electrical Inst.

THERMOCOUPLES—multi-junction
★ *Circle No.* 905
Anders Electronics
Bristol Inst.
British Central Elec.
Bryan Donkin
Bush, Beach, & Segner Bayley
Cambridge Instrument
Electroflo Meters
Elliott Brothers
Ether
Foster Instrument

★ *For further details circle on card facing page 214*

Hilger & Watts
Honeywell Controls
Land Pyrometers
Research & Control Inst.
Sifam Electrical Instruments
West Instrument

THERMOCOUPLES—rare metal
★ *Circle No.* 906
B.I.C.C.
Bailey Meters & Control
Bristol Inst.
British Central Elec.
British Sarozal
Bush, Beach, & Segner Bayley
Cambridge Instrument
Electroflo Meters
Elliott Brothers
Engelhard (Ind. Plat. Div.)
Ether
Foster Instrument
Foxboro-Yoxall
Griffin & George
Honeywell Controls
Industrial Pyrometer
Integra Leeds
James Gordon
Johnson Matthey
Kandem Electrical
Kelvin & Hughes
Land Pyrometers
Sifam Electric Instruments
Technograph
West Instrument
White Electrical Inst.

THERMOCOUPLES—vacuum
★ *Circle No.* 907
Anders Electronics
British Central Elec.
Foster Instrument
Foxboro-Yoxall
Hilger & Watts
Sangamo Weston
West Instrument

THERMOMETERS, bimetal
★ *Circle No.* 908
British Rototherm
Darton, F.
Electroflo Meters
Fuel Efficiency
Griffin & George
James Gordon
Negretti & Zambra
Newbold & Bulford
Smith & Sons (England), S.
Stanley, W. F.
Teddington Refrigeration
Zeal, G. H.

THERMOMETERS, filled system —pressure principle, gas filled
★ *Circle No.* 909
Bailey Meters & Control
Bristol Inst.
Cambridge Instrument
David Harcourt
Delta Technical Services
Electroflo Meters
Elliott Brothers
Elliott Nucleonics
Foxboro-Yoxall
James Gordon
Smith & Sons (England), S.
Sunvic Controls
Taylor Controls

THERMOMETERS, filled system —pressure principle, vapour filled
★ *Circle No.* 910
Bristol Inst.
British Rototherm
Budenberg Gauge
Cambridge Instrument
Coley Thermometers
David Harcourt
Delta Technical Services
Drayton Regulator
Electroflo Meters
Elliott Brothers
Foxboro-Yoxall
James Gordon
K.D.G. Instruments
Nottingham Thermometer
Payne & Griffiths
Smiths Industrial Inst.
Taylor Controls
Teddington Ind. Equip.
Zeal, G. H.

THERMOMETERS, filled system —volume principle, liquid filled
★ *Circle No.* 911
Bristol Inst.
British Steam Specialties
Delta Technical Services
Drayton Regulator
Elliott Brothers
Foxboro-Yoxall
Griffin & George
James Gordon
K.D.G. Instruments
Stanley, W. F.
Taylor Controls

THERMOMETERS, filled system —volume principle, mercury filled
★ *Circle No.* 912
British Rototherm
British Steam Specialties
Budenberg Gauge
Cambridge Instrument
Coley Thermometers
Drayton Regulator
Electrical Thermometer
Electro Methods
Engel & Gibbs
Griffin & George
K.D.G. Instruments
Negretti & Zambra
Nottingham Thermometer
Stanley, W. F.
Taylor Controls
Zeal, G. H.

THERMOMETERS, liquid-in-glass
★ *Circle No.* 913
British Steam Specialties
Darton, F.
Griffin & George
Goodmans Industries
Negretti & Zambra
Nottingham Thermometer
Short & Mason
Stanley, W. F.
Zeal, G. H.

THERMOSTATS. See also **Controllers**
★ *Circle No.* 914
A. M. Lock
Black Automatic Controls
Bristol Inst.
British Rototherm
British Sarozal
Cambridge Instrument
Crater Products
Danfoss
Delta Technical Services
Drayton Regulator
Electroflo Meters
Electro Methods
Evans Electronic Develop.
Fielden Electronics
Fuel Efficiency
Griffin & George
G.E.C.
James Gordon
Mycalex
Negretti & Zambra
Perl Controls
Process Control Gear
Pullin, R. B.
Rheostatic Co.
Salford Elec. Instruments
Sauter Controls
Short & Mason
Smith & Sons (England), S.
Spirax-Sarco
Stonebridge Electrical
Sunvic Controls
Teddington Ind. Equip.
Teddington Refrigeration
Unity Heating
Western Mfg. (Reading)

THICKNESS GAUGES— eddy current
★ *Circle No.* 915
Salford Elec. Instruments
Sperry Gyroscope

THICKNESS GAUGES— mechanical
★ *Circle No.* 916
Davy & United Instruments
Sigma Inst.

THICKNESS GAUGES— nucleonic
★ *Circle No.* 917
Baldwin Industrial Controls
Davy & United Instruments
Ekco Electronics
Elliott Brothers
Isotope Developments
Research & Control Inst.
Vidor Batteries

THICKNESS GAUGES— pneumatic
★ *Circle No.* 918
Joseph Lucas
Sigma Inst.
Thomas Mercer (Air Gauges)
Timothy Eaton
Vernon Instrument

THICKNESS GAUGES— ultrasonic
★ *Circle No.* 919
Aveley Electric
British Sarozal
Dawe Instruments
Farnell Instruments
Glass Developments
Kelvin & Hughes

THYRATRONS. See **Valves, electronic**

TIMERS. See also **Controllers, programme**
★ *Circle No.* 920
A.C.M. Electronics
A.E.I.
Airmec
Allied Electronics
Atkins Robertson
Automatic Telephone
Automation Consultants
B. & R. Relays
Bray, E. N.
Bristol Inst.
British Federal Welder
Brookhirst Igranic
Bruce Peebles
Burrell, A. G.
C.J.R.
Craven Electronics
Delta Technical Services
Devon Instruments
Dewhurst & Partner
Digital Engineering
Elcontrol
Electric Remote Control
Electrotechnic
Elliott Brothers
Ericsson Telephones
Erie Resistor
Evans Eletronic Develop.
Farnell Instruments
Graseby Instruments
Griffin & George
Hirst Electronics
H. & B. Precision Eng.
Kingston Control Systems
Labgear
Lancashire Dynamo Elect.
Landis & Gyr
Lindars Automation
Londex
Magneta Time Co.
Magnetic Controls
Mullard Equipment
Newman Industries
Nottingham Thermometer
Page Engineering
Panax Equipment
Photoelectronics (M.O.M.)
Racal Instruments
Radiatron
Rank Cintel
Research & Control Inst.
Robinson, D.
Sanders (Electronics), W. H.
Sargrove Electronics
Small Electric Motors
South London Elect. Equip.
S.S. Electronics
Sterling Instruments
Sutton Coldfield Elec. Eng.
T.A.L. Numatics
Thomas Mercer
Thomas Walker
Timothy Eaton
Trumeter
Unilag
Venner Electronics
Woden Transformer

TITRATION EQUIPMENT, automatic
★ *Circle No.* 921
Baird & Tatlock
Doran Instrument
Gallenkamp, A.
G.E.C.
Griffin & George
Nash & Thompson
Pye, W. G.
Research & Control Inst.

TORQUE CONVERTERS
★ *Circle No.* 922
Hobson, H. M.
Plessey Co.
Siemens Edison Swan
Woden Transformer

TRANSFER FUNCTION ANALYSERS. See **Frequency response analysers**

TRANSFORMERS — constant voltage
★ *Circle No.* 923
Advance Components
Aerocontacts
Andec
Belclere Co.
British Central Elec.
British Sarozal
English Electric
Fortiphone
Foster Transformers
Gresham Transformers
Oliver Pell
P.A.R.
Radiospares
Simmons Electrical Winding
Stewart Aero Supply
Whitetrade
Woden Transformer

TRANSFORMERS—differential
★ *Circle No.* 924
Aero Transformers
Andec
Belclere Coy
British Central Elec.
British Sarozal
Bruce Peebles
C.J.R.
Correx
Craven Electronics
Elliott Nucleonics
Fortiphone
Fred Ferraris
Gresham Transformers
Haddon Transformers
Parmeko
Radiospares
Simmons Electrical Winding
Smith Hobson
Stewart Aero Supply
Swartwout
Telemeters
Tinsley, H.
Woden Transformer

TRANSFORMERS—high temperature
★ *Circle No.* 925
Aero Transformers
Andec
British Sarazol
Brush Electrical
Belclere Co.
Express Transformers
Ferranti
Fortiphone
Gardners Radio
Gresham Transformers
Haddon Transformers
Oliver Pell
Parmeko
Plessey Co.
Smith Hobson
Stewart Aero Supply
Woden Transformer

TRANSFORMERS—instrument
★ *Circle No.* 926
Aero Transformers
Andec
Atkins Robertson
Aveley Electric
Berclere Co.
British Central Elec.
British Sarazol
Crompton Parkinson
English Electric
Ernest Turner
Everett Edgcumbe
Express Transformers
Ferranti
Fortiphone
Foster Transformers
Gardners Radio
G.E.C.
Gresham Transformers
Hackbridge & Hewittic
Kendall & Mousley
Nalder Bros. & Thompson
Oliver Pell
P.A.R.
Parmeko
Plessey Co.
Record Elec.
Salford Elec. Instruments
Sangamo Weston
Simmons Electrical Winding
Smith Hobson
Stewart Aero Supply
Telemeters
Tyer
White Electrical Inst.
Woden Transformer

TRANSFORMERS—power
★ *Circle No.* 927
Aero Transformers
Andec
Asquith Electrics
Atkins Robertson
British Central Elec.
British Sarazol
Bruce Peebles
Brush Electrical
C.J.R.
Correx
Crompton Parkinson
English Electric
Express Transformers
Ferranti
Fortiphone
Foster Transformers
Gardners Radio
G.E.C.
Gresham Transformers
Hackbridge & Hewittic
Haddon Transformers
Harvey Electronics
Hirst Electronics
Holiday & Hemmerdinger
J.D. Electronics
Johnson & Phillips
Law & Plumtree
Oliver Pell
P.A.R.
Parmcko
Plessey Co.
Phillips Control (G.B.)
Radiospares
Robinson, D.
Standard Telephones
Servo Units
Smith Hobson
S.S. Electronics
Stewart Aero Supply
Sykes, W. R.
Teledictor
Telemeters
Transformer & Electric
Westool
Whitetrade
Woden Transformer
Zenith Electric

TRANSFORMERS—sub-miniature
★ *Circle No.* 928
Aero Transformers
Andec
Ardente Acoustic Lab.
Atkins Robertson
Aveley Electric
Belclere Co.
Correx
Fortiphone
Gardners Radio
Gresham Transformers
Multitone Electric Co.
Oliver Pell
P.A.R.
Parmeko
Plessey Co.
Radiospares
Research & Control Inst.
Short Bros. & Harland
Smith Hobson
Stewart Aero Supply
Woden Transformer

TRANSDUCER. As this term is employed loosely in different industries, it has not been used as a generic heading covering measuring devices. Instead it has only been used twice, for **Displacement and Force Transducers**, *q.v.*, where it is implied that an electrical output is obtained. Elsewhere it is replaced by less ambiguous terms, such as detector, converter, etc.

TRANSISTORS
★ *Circle No.* 930
Associated Transistors
Brush Crystal Co.
Ferranti
G.E.C.
Joseph Lucas
Mullard
Newmarket Transistors
R.C.A. (G.B.)
Semiconductors
Siemens Edison Swan
Standard Telephones
Texas Instruments

TRANSMITTERS. See **Converters, electro-pneumatic and electro-hydraulic**

TUBING—capillary
★ *Circle No.* 931
Ellay Tubes
Glass Developments
Griffin & George
Johnson Matthey

TUBING—flexible metallic
★ *Circle No.* 932
Avica Equipment
Benton & Stone
Dunlop Rubber
High Pressure Components
Johnson & Phillips
Power Auxiliaries
Samson Controls
Sanders (Electronics), W. H.
Simplex Electric
Warden, A.

TUBING—glass
★ *Circle No.* 933
Glass Developments
Griffin & George

TUBING—plastic
★ *Circle No.* 934
Airtech
B.I.C.C.
Drallim Industries
Griffin & George
High Pressure Components
Johnson & Phillips
Permali
Polypenco
Radiospares
Warden, A.

TUBING—rubber
★ *Circle No.* 935
Airtech
Avica Equipment
Dunlop Rubber
Griffin & George
Hall & Hall
High Pressure Components
Precision Rubbers
Warden, A.

TURBIDIMETERS. See under **Photometric instruments**

ULTRASONIC INDUSTRIAL EQUIPMENT
★ *Circle No.* 936
Aveley Electric
British Sarazol
Bruce Peebles
Cawkell
C.N.S. Instruments
Cossor Instruments
Craven Electronics
Dawe Instruments
Farnell Instruments
Glass Developments
Kelvin & Hughes
Lintronic
Metrix Instruments
Mullard Equipment

UNISELECTORS. See **Switches, uniselector**

VALVE ACTUATORS, electric -motor-operated—multi-position type
★ *Circle No.* 937
Drayton Regulator
Electroflo Meters
Electro-Hydraulics
Foster Instrument
Foxboro-Yoxall
Fuel Efficiency
Hobson, H. M.
Hopkinsons
Limitorque Valve Controls
Miles-Hivolt
Plessey Co.
Rheostatic Co.
Swartwout
Teddington Ind. Equip.
Teleflex Products
Tully Engineering

VALVE ACTUATORS, electric -motor-operated—proportioning type
★ *Circle No.* 938
Drayton Regulator
Electroflo Meters
Electro-Hydraulics
Evershed & Vignoles
Foster Instrument
Foxboro-Yoxall
Fuel Efficiency
George Kent
Hobson, H. M.
Honeywell Controls
Limitorque Valve Controls
Miles-Hivolt

★ *For further details circle on card facing page 214*

Rheostatic Co.
Sauter Controls
Sperry Gyroscope
Stonebridge Electrical
Teddington Ind. Equip.
Teleflex Products
Tully Engineering

VALVE ACTUATORS, electric-motor-operated—reversing floating type
★ *Circle No.* 939
Drayton Regulator
Electroflo Meters
Electro-Hydraulics
Foster Instrument
Foxboro-Yoxall
Fuel Efficiency
Hobson, H. M.
Honeywell Controls
Miles-Hivolt
Rheostatic Co.
Stonebridge Electrical
Teddington Ind. Equip.

VALVE ACTUATORS, electric-motor-operated—two-position type
★ *Circle No.* 940
Alexander Controls
Drayton Regulator
Electroflo Meters
Electro-Hydraulics
Foster Instrument
Foxboro-Yoxall
Fuel Efficiency
George Kent
Hobson, H. M.
Honeywell Controls
Industrial Pyrometer
Limitorque Valve Controls
Miles-Hivolt
Plessey Co.
Rheostatic Co.
Sauter Controls
Stonebridge Electrical
Teddington Ind. Equip.
Teleflex Products

VALVE ACTUATORS, electro-hydraulically-operated
★ *Circle No.* 941
Armstrong Whitworth Equip.
Baldwin Industrial Controls
Bell Precision
Black Automatic Controls
Boulton Paul Aircraft
Dewrance
Dowty Equipment
Electroflo Meters
Electro-Hydraulics
Elliott Brothers
Elliott Nucleonics
Evershed & Vignoles
Fairey
Fisher Governor
H.M.L.
Hobson, H. M.
Hydraulics & Pneumatics
Isenthal
Keelavite Hydraulics
Lockheed Precision Products
Miles-Hivolt
Oliver Pell
Oswalds & Ridgway
Pratt Precision
Reavell-Fahie
Short Bros. & Harland
Smith & Sons (England), S.
Spenborough Engineering
Sperry Gyroscope
Teddington Ind. Equip.
Tully Engineering

VALVE ACTUATORS, electro-pneumatically-operated—cylinder
★ *Circle No.* 942
Air Automation
Automa Engineering
Bailey Meters & Control
Baldwin Industrial Controls
Black Automatic Controls
Dunlop Rubber
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Evershed & Vignoles
Fisher Governor
George Hughes
Hobson, H. M.
Hydraulics & Pneumatics
Martonair
Maxam Power
Midland Pneumatic
Miles-Hivolt
Oliver Pell
Schader's Son, A.
T.A.L. Numatics
Westinghouse Brake

VALVE ACTUATORS, electro-pneumatically-operated—motor
★ *Circle No.* 943
Electro-Hydraulics
Hobson, H. M.
Maxam Power
Miles-Hivolt
T.A.L. Numatics

VALVE ACTUATORS, hydraulically-operated—cylinder
★ *Circle No.* 944
Baldwin Industrial Controls
Bell Precision
Black Automatic Controls
Dowty Equipment
Dunlop Rubber
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Fairey
High Pressure Components
H.M.L.
Hobson, H. M.
Hydraulics & Pneumatics
Integral
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Lockheed Precision Products
Martonair
Maxam Power
Miles-Hivolt
Plessey Co.
Pratt Precision
Reavell-Fahie
Sperry Gyroscope
Stein-Atkinson
Vickers-Armstrong

VALVE ACTUATORS, hydraulically-operated—motor
★ *Circle No.* 945
Electro-Hydraulics
Fairey
H.M.L.
Hobson, H. M.
Joseph Lucas (H. & C.)
Keelavite Hydraulics
Lockheed Precision Products
Miles-Hivolt
Pratt Precision
Reavell-Fahie
Stein-Atkinson
Teddington Ind. Equip.
Vickers-Armstrong

VALVE ACTUATORS, mechanically-operated—rotary shaft
★ *Circle No.* 946
British Steam Specialities
Baldwin Industrial Controls
D.E.V. Engineering
Electro-Hydraulics
Hobson, H. M.
Limitorque Valve Controls
Miles-Hivolt
Pratt Precision
White Dental Mfg.

VALVE ACTUATORS, mechanically-operated—slip stem
★ *Circle No.* 947
Black Automatic Controls
Electro-Hydraulics
Miles-Hivot
Pratt Precision

VALVE ACTUATORS, pneumatically-operated—cylinder
★ *Circle No.* 948
Air Automation
Baldwin Industrial Controls
Bailey Meters & Control
Benton & Stone
Black Automatic Controls
Drayton Regulator
Dunlop Rubber
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Fisher Governor
Foxboro-Yoxall
George Hughes
George Kent
Globe Pneumatic Eng.
Hobson, H. M.
Hydraulics & Pneumatics
James Gordon
Lang Pneumatic
Martonair
Maxam Power
Midland Pneumatic
Miles-Hivolt
Pressure Control
Schrader's Son, A.
T.A.L. Numatics
Westinghouse Brake

VALVE ACTUATORS, pneumatically-operated—diaphragm motor
★ *Circle No.* 949
Black Automatic Controls
Baldwin Industrial Controls
Blakeborough
Crosby Valve & Eng.
Elliott Brothers
Elliott Nucleonics
Elec. Steam & Mining
Electro-Hydraulics
Foxboro-Yoxall
Fisher Governor
Hobson, H. M.
Honeywell Controls
Hunt & Mitton
James Gordon
Miles-Hivolt
Samson Controls
Sauter Controls
T.A.L. Numatics
Taylor Controls

VALVE ACTUATORS, pneumatically-operated—gear-driven
★ *Circle No.* 950
Blakeborough
Electro-Hydraulics
James Gordon
Limitorque Valve Controls
T.A.L. Numatics

VALVE ACTUATORS, pneumatically-operated—piston motor
★ *Circle No.* 951
Drayton Regulator
Electro-Hydraulics
Globe Pneumatic Eng.
Hobson, H. M.
James Gordon
Limitorque Valve Controls
Miles-Hivolt
T.A.L. Numatics

VALVE ACTUATORS, pneumatically-operated—rotary vane
★ *Circle No.* 952
Kinetrol

VALVE ACTUATORS, self-operated (internal-pilot operated valves, viz. reducing valves and self-contained valves)
★ *Circle No.* 953
Air Automation
Benton & Stone
Black Automatic Controls
Blakeborough
Crosby Valve & Eng.
Dewrance
Dowty Equipment
Dunlop Rubber
Drayton Regulator
Elec. Steam & Mining
Electro-Hydraulics
Fairey
Fisher Governor
H.M.L.
Integral
Isenthal
Lang Pneumatic
Lockheed Precision Products
Miles-Hivolt
Norgren, C. A.
Normalair
Oswalds & Ridgway
Platon, G. A.
Pratt Precision
Pressure Control
Samson Controls
Short Bros. & Harland
Smith & Sons (England), S.
Spirax-Sarco
Teddington Ind. Equip.
Teddington Refrigeration
T.A.L. Numatics
Taylor Controls
Woden Transformer
Vickers-Armstrong

VALVE ACTUATORS, solenoid-operated—diaphragm type
★ *Circle No.* 954
Benton & Stone
Black Automatic Controls
Drayton Regulator
Electro-Hydraulics
Hobson, H. M.
Laycock Engineering
Magnetic Valve
Meynell
Miles-Hivolt
Teddington Ind. Equip.
Teddington Refrigeration
T.A.L. Numatics
Woden Transformer
Williams (B'ham), R. A.

VALVE ACTUATORS, solenoid-operated—pilot type
★ *Circle No.* 955
Air Automation
Benton & Stone
Baldwin Industrial Controls
Black Automatic Controls
Dewrance
Dowty Equipment
Drayton Regulator
Dunlop Rubber
Electro-Hydraulics
Electro-Mechanical Systems
George Hughes
H.M.L.
Hobson, H. M.
Jones Tate
Keelavite Hydraulics
Lang Pneumatic
Laycock Engineering
Magnetic Valve
Maxam Power
Miles-Hivolt
Pratt Precision
Schrader's Son, A.
S.E. Laboratories
Smith & Sons (England), S.
Stein-Atkinson
Teddington Ind. Equip.
T.A.L. Numatics
Williams (B'ham), R. A.
Woden Transformer

VALVES, ELECTRONIC— amplifying
★ *Circle No.* 956
Aerocontacts
Cossor Instruments
E.M.I. Electronics
English Electric Valve
Farnell Instruments
Ferranti
G.E.C.
Hivac
Holiday & Hemmerdinger
Lee Products
Marconi, W. T.
Mullard
Perl Controls
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones
Stewart Aero Supply

VALVES, ELECTRONIC— cold-cathode
★ *Circle No.* 957
Aerocontacts
Ericsson Telephones
Farnell Instruments
Ferranti
G.E.C.
Hivac
Holiday & Hemmerdinger
Lee Products
Marconi, W. T.
Mullard
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones
Stewart Aero Supply

VALVES, ELECTRONIC— detecting
★ *Circle No.* 958
Aerocontacts
Cossor Instruments
Ferranti
G.E.C.
Holiday & Hemmerdinger
Lee Products
Marconi W.T.
Mullard
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones
Stewart Aero Supply

VALVES, ELECTRONIC— electrometer
★ *Circle No.* 959
Ferranti
Hivac
Holiday & Hemmerdinger
Mullard
R.C.A.(G.B.)
Stewart Aero Supply

VALVES, ELECTRONIC— power output
★ *Circle No.* 960
Aerocontacts
English Electric Valve
Farnell Instruments
Ferranti
G.E.C.
Hivac
Holiday & Hemmerdinger
Lee Products
Marconi W.T.
Mullard
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones

VALVES, ELECTRONIC— rectifying
★ *Circle No.* 961
A.E.I.
Aerocontacts
Cossor Instruments
EMI Electronics
English Electric Valve
Farnell Instruments
Ferranti
G.E.C.
Holiday & Hemmerdinger
Lee Products
Marconi, W. T.
Miles-Hivolt
Mullard
Perl Controls
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones
Stewart Aero Supply

VALVES, ELECTRONIC— sub-miniature
★ *Circle No.* 962
Aerocontacts
Automatic Telephone
Farnell Instruments
G.E.C.
Hivac
Holiday & Hemmerdinger
Mullard
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones
Stewart Aero Supply

VALVES, ELECTRONIC— thermal delay
★ *Circle No.* 963
Coventry Controls
Hivac
Holiday & Hemmerdinger
Mullard
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones

VALVES, ELECTRONIC— thyratron
★ *Circle No.* 964
A.E.I.
Aerocontacts
EMI Electronics
English Electric Valve
Farnell Instruments
Ferranti
G.E.C.
Hivac
Holiday & Hemmerdinger
Marconi, W. T.
Mullard
R.C.A. (G.B.)
Siemens Edison Swan
Standard Telephones

VALVES, FLUID—angle
★ *Circle No.* 965
Appleby & Ireland
Black Automatic Controls
Blakeborough
British Steam Specialties
Cockburns
Crosby Valve & Eng.
D.E.V. Engineering
Dewrance
Drayton Regulator
Electro-Hydraulics
Fisher Governor
Foxboro-Yoxall
Hopkinsons
H.M.L.
Hunt & Mitton
Hydraulics & Pneumatics
Inness
James Gordon
Joshua Hindle
Meynell & Sons
Pressure Control
Reavell-Fahie
Rheostatic Co.
Saunders Valve
Sydney Smith
Thos. Ryder
Vickers-Armstrong

VALVES, FLUID—butterfly
★ *Circle No.* 966
Alexander Controls
Armstrong Whitworth Equip.
Bailey, Sir W. H.
Blakeborough
British Arca Regulators
British Steam Specialties
Bryan Donkin
Cockburns
Crosby Valve & Eng.
D.E.V. Engineering
Dewrance
Drayton Regulator
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Elliott Nucleonics
Fisher Governor
Foxboro-Yoxall
Fuel Efficiency
H.M.L.
Hopkinsons
Heaton & Co.
Inness
James Gordon
Joshua Hindle
Normalair
Reavell-Fahie
Rheostatic Co.
Saunders Valve
Sauter Controls
Stonebridge Electrical
Thos. Ryder

VALVES, FLUID—control
★ *Circle No.* 967
Air Automation
Alexander Controls
Appleby & Ireland
Armstrong Whitworth Equip.
Avery Hardoll
Bailey, Sir W. H.
Baldwin Industrial Controls
Birfield Indsutries
Black Automatic Controls
Blakeborough
British Arca Regulators
British Steam Specialties
Cockburns
Crosby Valve & Eng.
Dewrance
Dowty Equipment
Dowty Hydraulic Units
Drallim Industries
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Ether
Exactor
Feeny & Johnson
Fisher Governor
Foxboro-Yoxall
George Ellison
Hamworthy Eng.
High Pressure Components
H.M.L.
Hobson, H. M.
Honeywell Controls
Hopkinsons
Hunt & Mitton
Hydraulics & Pneumatics
Inness
Integral
James Gordon
Joshua Hindle & Sons
Keelavite Hydraulics
Laycock Engineering
Martonair
Meynell & Sons
Midland Pneumatic
Palatine Tool & Eng.
Platon, G. A.
Pratt Precision
Pressure Control
Rheostatic Co.
Saunders Valve
Samson Controls
Sauter Controls
S.E. Laboratories
Simmonds Aerocessories
Smith & Sons (England), S.
Smiths Jacking Systems
Spenborough Engineering
Stein Atkinson
Stewart Aero Supply
Stonebridge Electrical
Stuart Davis
Sydney Smith
T.A.L. Numatics
Taylor Controls
Thos. Ryder
Vickers
Vickers-Armstrong
Western Mfg. (Reading)

VALVES, FLUID—damper
★ *Circle No.* 968
B. & D. Swift

★ For further details circle on card facing page 214

D.E.V. Engineering
Electro-Hydraulics
Fisher Governor
Inness
Keelavite Hydraulics
Simmonds Aerocessories
Stewart Aero Supply
Saunders Valve
Thos. Ryder

VALVES, FLUID—diaphragm
★ *Circle No.* 969
Air Automation
Alexander Controls
Appleby & Ireland
Baldwin Industrial Controls
Birfield Industries
Black Automatic Controls
British Steam Specialties
Bryan Donkin
Cockburns
Crosby Valve & Eng.
Drallim Industries
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Elliott Nucleonics
Fisher Governor
George Ellison
Heaton & Co.
H.M.L.
Honeywell Controls
Hymatic Engineering
Inness
James Gordon
Laycock Engineering
Martonair
Meynell & Sons
Pressure Control
Samson Controls
Sauter Controls
Taylor Controls
Thos. Ryder

VALVES, FLUID—double-ported globe
★ *Circle No.* 970
Alexander Controls
Black Automatic Controls
Blakeborough
British Steam Specialties
Crosby Valve & Eng.
Dewrance
Electroflo Meters
Electro-Hydraulics
Fisher Governor
Foxboro-Yoxall
High Pressure Components
H.M.L.
Honeywell Controls
Hunt & Mitton
Hydraulics & Pneumatics
Inness
Meynell & Sons
Taylor Controls
Thos. Ryder

VALVES, FLUID—fireproof
★ *Circle No.* 971
Alexander Controls
Appleby & Ireland
Electro-Hydraulics
Flight Refuelling
Inness
Thos. Ryder

VALVES, FLUID—flow dividing
★ *Circle No.* 972
Armstrong Whitworth Equip
Birfield Industries
Blakeborough
British Arca Regulators
Crosby Valve & Eng.
Dowty Equipment
Drayton Regulator
Electroflo Meters
Electro-Hydraulics
Fisher Governor
Foxboro-Yoxall
George Ellison
Hamworthy Eng.
H.M.L.
Hobson, H. M.
Honeywell Controls
Hunt & Mitton
Inness
Integral
Keelavite Hydraulics
Meynell & Sons
Normalair
Pressure Control
Rheostatic Co.
Smith & Sons (England), S.
Smiths Jacking Systems
Spirax-Sarco
Stein-Atkinson
Stuart Davis
Taylor Controls
Thos. Ryder
Vickers-Armstrong

VALVES, FLUID—gate
★ *Circle No.* 973
Appleby & Ireland
Blakeborough
British Steam Specialties
Bryan Donkin
Cockburns
Dewrance
Electro-Hydraulics
H.M.L.
Heaton & Co.
Hopkinsons
Inness
Joshua Hindle & Sons
Meynell & Sons
Saunders Valve
Sydney Smith
Thos. Ryder
Vickers
Vickers-Armstrong

Warden, A.

VALVES, FLUID—miniature
★ *Circle No.* 974
Air Automation
Alexander Controls
Appleby & Ireland
Black Automatic Controls
Dowty Equipment
Electro-Hydraulics
Fisher Governor
High Pressure Components
H.M.L.
Hobson, H. M.
Hymatic Engineering
Martonair
Pressure Control
Saunders Valve
Spenborough Engineering
Thos. Ryder

VALVES, FLUID—non-return
★ *Circle No.* 975
Air Automation
Armstrong Whitworth Equip.
Appleby & Ireland
Baldwin Industrial Controls
Bailey, Sir W. H.
Birfield Industries
Blakeborough
British Steam Specialties
Cockburns
Danfoss
Dewrance
Dowty Equipment
Dowty Hydraulic Units
Dunlop Rubber
Electro-Hydraulics
Exactor
Feeny & Johnson
Flight Refuelling
George Ellison
Heaton & Co.
High Pressure Components
H.M.L.
Hobson, H. M.
Hopkinsons
Hunt & Mitton
Hymatic Engineering
Inness
Integral
Joshua Hindle & Sons
Keelavite Hydraulics
Kontak Manufacturing
Laycock Engineering
Martonair
Meynell & Sons
Midland Pneumatic
Normalair
Pratt Precision
Pressure Control
Saunders Valve
S.E. Laboratories
Short Bros. & Harland
Smith & Sons (England), S.
Smiths Jacking Systems
Spenborough Engineering
Stein-Atkinson
Stewart Aero Supply
Sydney Smith
T.A.L. Numatics
Thos. Ryder
Vickers
Vickers-Armstrong
Warden, A.
[illegible]

VALVES, FLUID—pressure reducing
★ *Circle No.* 976
Air Automation
Armstrong Whitworth Equip.
Appleby & Ireland
Bailey, Sir W. H.
Baldwin Industrial Controls
Birfield Industries
Black Automatic Controls
Blakeborough
British Arca Regulators
British Steam Specialties
Bryan Donkin
Cockburns
Crosby Valve & Eng.
Dewrance
Dowty Equipment
Drayton Regulator
Dunlop Rubber
Elec. Steam & Mining
Electroflo Meters
Electro-Hydraulics
Electro-Mechanical Systems
Elliott Nucleonics
Fisher Governor
Foxboro-Yoxall
George Ellison
George Kent
High Pressure Components
H.M.L.
Hobson, H. M.
Honeywell Controls
Hopkinsons
Hunt & Mitton
Hymatic Engineering
Inness
Integral
James Gordon
Keelavite Hydraulics
Martonair
Midland Pneumatic
Norgren, C. A.
Normalair
Payne & Griffiths
Plessey Co.
Pratt Precision
Pressure Control
Samson Controls
Samuel Birkett
S.E. Laboratories
Short Bros. & Harland
Smith & Sons (England), S.
Smiths Jacking Systems

Stein-Atkinson
Stewart Aero Supply
Stuart Davis
Sydney Smith
Taylor Controls
Thos. Ryder
Vickers
Vickers-Armstrong
Warden, A.
Williams & James

VALVES, FLUID—sequence
★ *Circle No.* 977
Baldwin Industrial Controls
Black Automatic Controls
British Arca Regulators
Dewrance
Drayton Regulator
Dunlop Rubber
Electro-Hydraulics
George Ellison
Hobson, H. M.
Keelavite Hydraulics
Martonair
Midland Pneumatic
Pratt Precision
Short Bros. & Harland
Smith & Sons (England), S.
Stein-Atkinson
Thos. Ryder
Vickers
Vickers-Armstrong

VALVES, FLUID—single-ported globe
★ *Circle No.* 978
Alexander Controls
Blakeborough
British Steam Specialties
Crosby Valve & Eng.
Electroflo Meters
Electro-Hydraulics
Fisher Governor
High Pressure Components
Honeywell Controls
Hunt & Mitton
Inness
Taylor Controls
Thos. Ryder

VALVES, FLUID—split-globe
★ *Circle No.* 979
Electroflo Meters
Electro-Hydraulics
Honeywell Controls
Inness
Meynell & Sons
Thos. Ryder

VALVES, FLUID—three-way
★ *Circle No.* 980
Air Automation
Baldwin Industrial Controls
Black Automatic Controls
Blakeborough
British Arca Regulators
British Steam Specialties
Cockburns
Crosby Valve & Eng.
Dowty Equipment
Dowty Hydraulic Units
Drallim Industries
Drayton Regulator
Electroflo Meters
Electro-Hydraulics
Fisher Governor
Foxboro-Yoxall
Fuel Efficiency
George Ellison
Honeywell Controls
Hopkinsons
Hunt & Mitton
Hydraulics & Pneumatics
Inness
Integral
Joshua Hindle & Sons
Keelavite Hydraulics
Martonair
Meynell & Sons
Pratt Precision
Pressure Control
Rheostatic Co.
Samson Controls
Sauter Controls
Saunders Valve
S.E. Laboratories
Smiths Jacking Systems
Spenborough Engineering
Stonebridge Electrical
Stuart Davis
Thos. Ryder
Taylor Controls
Vickers
Spirax-Sarco
Vickers-Armstrong

VALVES, FLUID—venturi throat
★ *Circle No.* 981
Black Automatic Controls
Blakeborough
Cockburns
Crosby Valve & Eng.
Dewrance
Electroflo Meters
Electro-Hydraulics
Fisher Governor
Foxboro-Yoxall
Hopkinsons
Hymatic Engineering
Inness
Thos. Ryder

VALVE POSITIONERS, pneumatic—force-balance
★ *Circle No.* 982
Black Automatic Controls
Crosby Valve & Eng.
Drayton Regulator
Elliott Brothers
Elliott Nucleonics

Fisher Governor
Foxboro-Yoxall
Hobson, H. M.
James Gordon
Martonair
Reavell-Fahie
Samson Controls
Sunvic Controls
Taylor Controls
Westinghouse Brake

VALVE POSITIONERS, pneumatic—spring-balance
★ *Circle No.* 983
Black Automatic Controls
British Arca Regulators
Bailey Meters & Control
Drayton Regulator
Electroflo Meters
George Kent
James Gordon
Taylor Controls

VALVE POSITION INDICATORS
★ *Circle No.* 984
British Steam Specialties
Bruce Peebles
Craven Electronics
D.E.V. Engineering
Dowty Equipment
Drayton Regulator
Electroflo Meters
Evershed & Vignoles
Fisher Governor
Foxboro-Yoxall
Hopkinsons
Record Elec.
Samson Controls
Smiths Industrial Inst.
Sunvic Controls
Teddington Ind. Equip.
Telemeters
Trumeter

VIBRATION—analysers
★ *Circle No.* 985
Armstrong Whitworth Equip.
Aveley Electric
B. & K. Labs.
Brush Electrical
Claude Lyons
Dawe Instruments
Epsylon Industries
Fairey
Farnell Instruments
Giesler, C. F. R.
James Scott Elec. Eng.
Lancashire Dynamo Elect.
Muirhead
Research & Control Inst.
Royston Instruments
Sperry Gyroscope

VIBRATION—generators
★ *Circle No.* 986
Bryan Savage
B. & K. Labs.
Epsylon Industries
Farnell Instruments
Goodmans Industries
Research & Control Inst.
Sargrove Electronics
Sinex Engineering

VIBRATION—mountings
★ *Circle No.* 987
Cementation
Dunlop Rubber
Expanded Rubber
Fairey
Howard Clayton-Wright

VIBRATION—testing equipment
★ *Circle No.* 988
A.E.I.
Allied Electronics
Armstrong Whitworth Equip.
Aveley Electric
B. & K. Labs.
Bryan Savage
Cambridge Instrument
Dawe Instruments
EMI Electronics
Ericsson Telephones
Farnell Instruments
G.E.C.
Giesler, C. F. R.
Gresham Developments
Grünther Ind. Developments
Hendrey Relays
Magnetic Equipment
Muirhead
Paton Hawksley
Research & Control Inst.
Telecommunication Inst.
Wayne Kerr Labs.

VISCOSITY INDICATORS, continuous reading
★ *Circle No.* 989
Dobbie McInnes
Elliott Brothers
Ferranti
Kandem Electrical
Short & Mason
Timothy Eaton

VOLTAGE REGULATORS
★ *Circle No.* 990
Advance Components
A.E.I.
Airmec
Allied Electronics
Bailey Meters & Control
British Central Elec.
British Elec. Resistance
British Sarazol
Brookhirst Igranic

Bruce Peebles
Brush Electrical
Bryans Aeroequipment
Claude Lyons
Coventry Controls
Cox Walkers
Craven Electronics
English Electric
Electrical Apparatus
Electro Methods
Ferranti
Foster Transformers
Fuller Electric
G.E.C.
Gresham Developments
Gresham Transformers
Hirst Electronic
Isenthal
John Morris Elec. Eng.
Langham Thompson, J.
Laurence Scott
Marconi, W. T.
Newton Brothers
Parmeko
Plessey Co.
Sanders (Electronics), W. H.
Servomex Controls
Stewart Aero Supply
Vernons Industries
Zenith Electric

WARD LEONARD SETS
★ *Circle* [illegible]. 991
A.E.I.
Albert Mann Eng.
British Central Elec.
Bruce Peebles
Brush Electrical
Crompton Parkinson
English Electric
G.E.C.
Laurence Scott
Mawdsley's
Sanders (Electronics), W. H.
Vernons Industries

WATER PURIFICATION PLANT
★ *Circle No.* 992
Elga Products
Permutit

WEIGHERS, INDUSTRIAL. See also Load cells

WEIGHERS, INDUSTRIAL—electronic systems
★ *Circle No.* 993
Adequate Weighers
Air Trainers Link
Albert Mann Eng.
Ariel Sound
Automa Engineering
Automation Consultants
Bruce Peebles
Craven Electronics
Davy & United Instruments
Elcontrol
Electroweighers
EMI Electronics
Ericsson Telephones
Industrial Products
Lancashire Dynamo Elect.
Merrick Scale Mfg. Co.
Parsons, S.
Radiovisor Parent
Research & Control Inst.
Richardson Scale
S.E. Laboratories
Sinex Laboratories
Solartron
Telecommunication Inst.

WEIGHERS, INDUSTRIAL—hydraulic systems
★ *Circle No.* 994
Adequate Weighers
Industrial Products
Parsons, S.
Plessey Co.
Sperry Gyroscope
Sydney Smith
Taylor Controls

WEIGHERS, INDUSTRIAL—mechanical systems
★ *Circle No.* 995
Adequate Weighers
Aero Transformers
Air Trainers Link
Ariel Sound
Automation Consultants
Geo. Salter
Lindars Automation
Merrick Scale Mfg.
Parsons, S.
Richardson Scale
Valley Products
Wallace & Tiernan

WEIGHERS, INDUSTRIAL—pneumatic systems
★ *Circle No.* 996
Adequate Weighers
Electroflo Meters
Foxboro-Yoxall
Merrick Scale Mfg.
Parsons, S.
Richardson Scale
Taylor Controls
Wallace & Tiernan

WIRE RECORDERS. See Magnetic wire recorders
★ *Circle No.* 997

WOBBE INDEX INSTRUMENTS
Ernest Turner
George Kent
Sigma Inst.

★ *For further details circle on card facing page 214*

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